HUC 10280103 – Lower Grand
Water body IDs: 619 and 623
Pollutant(s): Pathogens as indicated by *Escherichia coli*

Total Maximum Daily Load

for

Medicine Creek and Little Medicine Creek

Grundy, Mercer, Putnam, and Sullivan counties

Pollutants of concern: Pathogens

Submitted: March 22, 2019
Approved: May 28, 2019

Prepared by: Watershed Protection Section

WATER BODY SUMMARY
Total Maximum Daily Loads (TMDLs) for Medicine Creek and Little Medicine Creek
Pollutant: Pathogens as indicated by *Escherichia coli (E. coli)*


Location of watersheds in Missouri

Name: Medicine Creek
Location: Grundy, Sullivan, and Putnam counties

Name: Little Medicine Creek
Location: Grundy and Mercer counties

8-digit Hydrologic Unit Code (HUC):[1]
10280103 – Lower Grand Subbasin

10-digit HUC Subwatersheds
1028010301 – Little Medicine Creek
1028010302 – Headwaters Medicine Creek

Water Body Identification Number (WBID) and Hydrologic Class:[2]
Medicine Creek: WBID 619 – Class P
Little Medicine Creek: WBID 623 – Class P

Designated Uses:[3]
Irrigation
Livestock and wildlife protection
Human health protection
Protection and propagation of fish, shellfish and wildlife – warm water habitat
Whole body contact recreation category B
Secondary contact recreation

Impaired Use:
Whole body contact recreation category B

Pollutant Identified on the 303(d) List:
Escherichia coli (E. coli) (fecal indicator bacteria)

Identified Sources on 303(d) List:
Rural nonpoint sources

Length and Location of Impaired Segment:
Medicine Creek: 43.8 mi (70.5 km), from Section 9, Township 61N, Range 22W to state line
Little Medicine Creek: 39.8 mi (64.1 km), from mouth to state line

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[1] Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 2,270 8-digit hydrologic units (USGS and NRCS 2013). A hydrologic unit is a drainage area delineated to nest in a multilevel, hierarchical drainage system. A hydrologic unit code is the numerical identifier of a specific hydrologic unit consisting of a 2-digit sequence for each specific level within the delineation hierarchy (FGDC 2003).

[2] For hydrologic classes see 10 CSR 20-7.031(1)(F). Class P streams maintain permanent flow even in drought periods.

[3] For designated uses see 10 CSR 20-7.031(1)(C) and 10 CSR 20-7.031 Table H. Presumed uses are assigned per 10 CSR 20-7.031(2)(A) and (B) and are reflected in the Missouri Use Designation Dataset described at 10 CSR 20-7.031(2)(E).

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1. Introduction

The Missouri Department of Natural Resources in accordance with Section 303(d) of the federal Clean Water Act is establishing this Medicine Creek and Little Medicine Creek total maximum daily load (TMDL). This TMDL report addresses "water quality limited segments" that were approved by the U.S. Environmental Protection Agency (EPA) for inclusion on Missouri's 2016 303(d) List of impaired waters on July 12, 2016.[4] Medicine Creek and Little Medicine Creek were first listed in 2006 and have been determined to be impaired by disease causing pathogens as indicated by the presence of *Escherichia coli* (*E. coli*) bacteria, which occur at concentrations that exceed Missouri's water quality criteria for this pollutant.[5] This report addresses the pathogen impairment of these water bodies by establishing TMDLs for *E. coli*.

Section 303(d) of the federal Clean Water Act and Title 40 of the Code of Federal Regulations (CFR) Part 130 require states to develop TMDLs for waters not meeting applicable water quality standards. Missouri's Water Quality Standards at Title 10 of the Code of State Regulation (CSR) Division 20 Chapter 7.031 consist of three major components: designated uses, water quality criteria to protect those uses, and an antidegradation policy. The purpose of a TMDL is to determine the loading capacity of a specific pollutant that a water body can assimilate without exceeding the water quality standards for that water body. The TMDL process quantitatively assesses impairment factors so that water quality-based controls can be established to reduce pollutant loading and to restore and protect the quality of Missouri's water resources. Based on the relationship between pollutant sources and in-stream water quality conditions, a TMDL is the sum of a wasteload allocation and a load allocation (40 CFR 130.2) with a margin of safety (Clean Water Act section 303(d)(1)(c)). The wasteload allocation is the fraction of the loading capacity apportioned to existing or future point sources. The load allocation is the fraction of the loading capacity apportioned to existing or future nonpoint sources and natural background. The margin of safety is a percentage of the TMDL that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality (40 CFR 130.7), any uncertainty associated with the model assumptions, and data inadequacies.

2. Watershed Descriptions

Medicine Creek and Little Medicine Creek are located in northern Missouri within the Lower Grand subbasin, which is cataloged by the U.S. Geological Survey (USGS) as the 8-digit hydrologic unit code (HUC) 10280103. Within this subbasin, the 10-digit HUC 1028010302 delineates the 235.3 square mile (609.4 square kilometer) watershed that drains the impaired segment of Medicine Creek. Approximately 75 mi^2 (194 km^2) of this watershed are located in Iowa. The Little Medicine Creek watershed is 107.6 mi^2 (278.6 km^2) and is delineated by the 10-digit HUC 1028010301. Approximately 1.1 mi^2 (2.8 km^2) of the Little Medicine Creek watershed are located in Iowa.

Medicine Creek originates in Wayne County, Iowa at the mouth of East Fork Medicine Creek and flows south approximately 2.0 mi (3.2 km) before entering Missouri. The Missouri Use Designation

[4] A water quality limited segment is any segment where it is known that water quality does not meet applicable water quality standards, or is not expected to meet applicable water quality standards, even after the application of the technology-based effluent limitations required by sections 301(b) and 306 of the Clean Water Act (40 CFR 130.2).

[5] The Department maintains current and past 303(d) lists and corresponding assessment worksheets online at dnr.mo.gov/env/wpp/waterquality/303d/303d.htm.

Dataset[6] identifies approximately 43.8 mi (70.5 km) of Medicine Creek, from the state border to the outlet of 10-digit HUC 1028010302, as water body identification number (WBID) 619.[7] Little Medicine Creek originates in Wayne County, Iowa approximately 1.3 mi (2 km) upstream of the state border. The impaired segment of Little Medicine Creek, identified as WBID 623, flows 39.8 mi (64.1 km) from the state border to the outlet of the 10-digit HUC 1028010301. Figure 1 presents a map showing the locations of the impaired water body segments and their watersheds.

2.1 Geology, Physiography, and Soils

The Medicine Creek and Little Medicine Creek watersheds are located within the Grand/Chariton ecological drainage unit, which is an area that covers approximately 8,300 square miles of northcentral Missouri. Ecological drainage units are groups of watersheds that have similar biota, geography, and climate characteristics (USGS 2009). Streams within this drainage unit are typically turbid with sandy substrates and gain little or no flow from groundwater due to extreme rarity of springs in the region (MoRAP 2005).

These watersheds are also located in the Loess Flats and Till Plains level IV ecoregion. Ecoregions are areas with similar ecosystems and environmental resources and are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components. By recognizing spatial differences in ecosystems, ecoregions stratify the environment by its probable response to disturbance (Chapman et al. 2002). Ecoregions are further defined in Missouri's Water Quality Standards at 10 CSR 20-7.031(1)(H). As its name implies, the Loess Flats and Till Plains ecoregion is characterized primarily by its sediments comprised of loess deposits and glacial till. This ecoregion has relatively flat terrain and soil erosion is a common ecological concern. Groundwater in this ecoregion is typically saline (Chapman et al. 2002).

Together the Medicine Creek and Little Medicine Creek watersheds are comprised of 81 individual soil types. Although soils in these watersheds are varied, they can be categorized based on similar runoff potentials into hydrologic soil groups. A hydrologic soil group indicates the rate at which water enters the soil profile under conditions of a bare, thoroughly wetted soil surface, which in turn may affect the potential amount of water entering the stream as runoff (NRCS 2009). Table 1 provides a summary of the hydrologic soil groups in the Missouri portions of the Medicine Creek and Little Medicine Creek watersheds and Figure 2 shows their distribution. Group A represents soils with the highest rate of infiltration and the lowest runoff potential. Group D represents the group with the lowest rate of infiltration and highest potential for runoff. Many wet soils fall in dual soil groups (e.g., Group C/D) due to the presence of a high water table saturating the surface. The dual hydrologic soil groups account for this by providing both the drained and undrained condition of the soil.[8] In the Medicine Creek and Little Medicine Creek watersheds, areas where soils were not rated are areas described by the U.S. Department of Agriculture's Web Soil Survey as being open water.[9] It should be noted that hydrologic soil groups are only one factor influencing runoff in the watershed. Impervious surfaces, vegetative cover, slope, rainfall intensity, and land use can significantly influence the potential for runoff despite the hydrologic soil groups present.

[6] The Missouri Use Designation Dataset documents the names and locations of the state's rivers, streams, lakes and reservoirs, which have been assigned designated uses (10 CSR 20-7031 (1)(P)).
[7] Water body identification numbers (WBIDs) are unique to each water body or water body segment listed in the classification and use designation tables of 10 CSR 20-7.031 and delineated in the Missouri Use Designation Dataset.
[8] For the purpose of hydrologic soil group, adequately drained means that the seasonal high water table is kept at least 24 inches (60 centimeters) below the surface in a soil where it would be higher in a natural state (NRCS 2009).
[9] https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

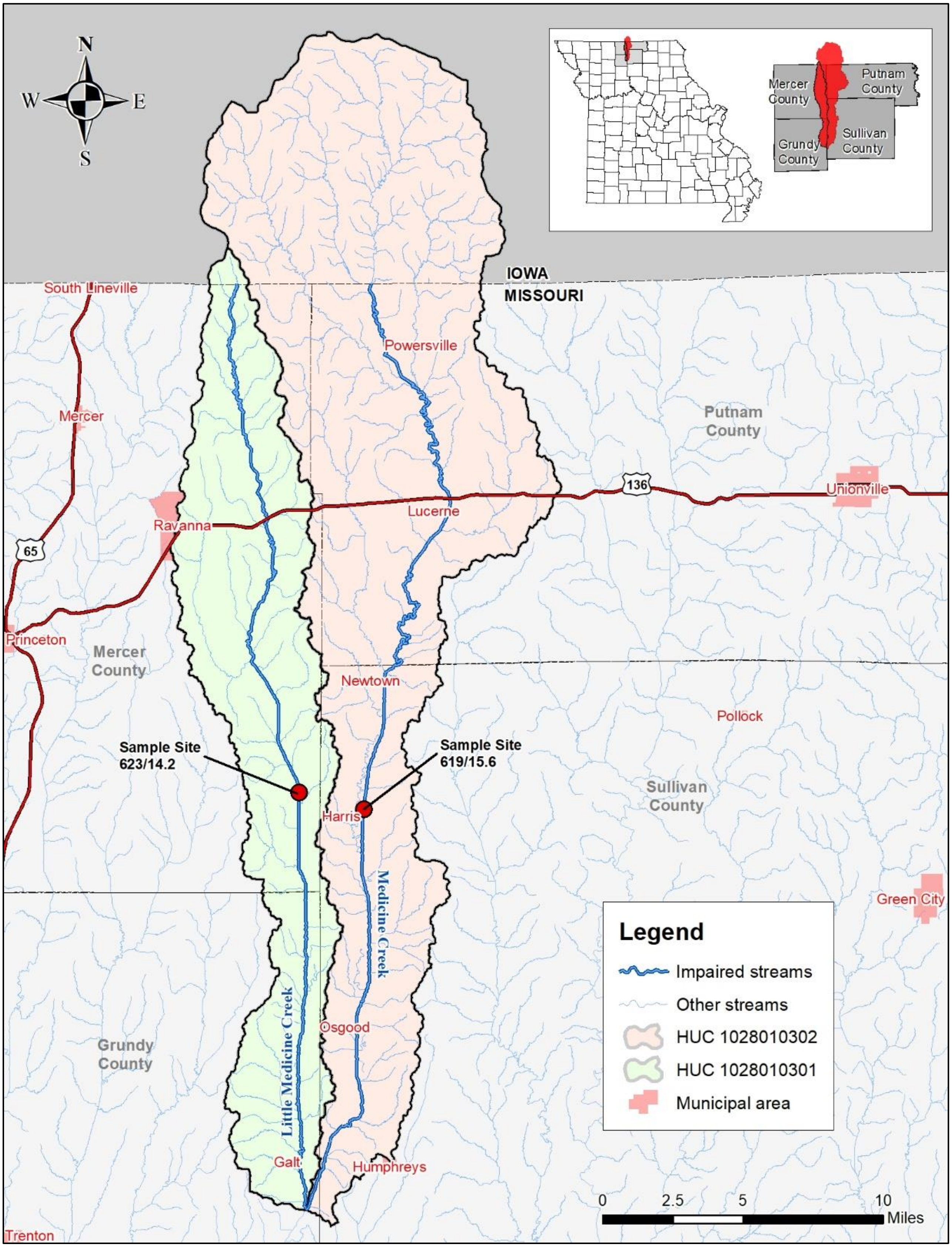

Figure 1. The Medicine Creek and Little Medicine Creek watersheds

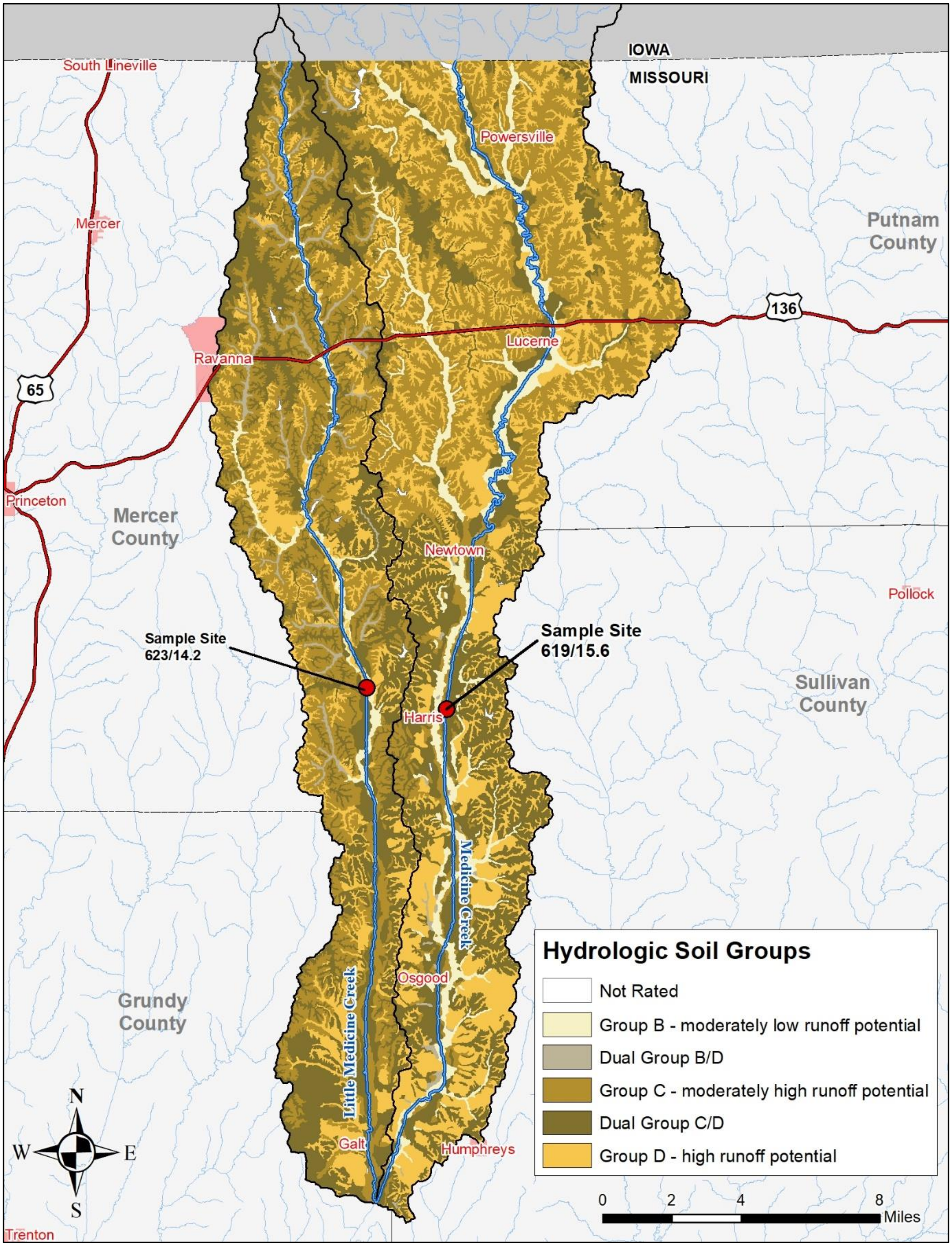

Figure 2. Hydrologic soil groups in the Medicine and Little Medicine watersheds

Table 1. Hydrologic soil groups in the Medicine and Little Medicine watersheds (NRCS 2011)

Hydrologic Soil Group	Medicine Creek Watershed Area			Little Medicine Creek Watershed Area		
	mi^2	km^2	%	mi^2	km^2	%
Group A	0	0	0.00	0	0	0.00
Group B	15.37	39.80	9.58	3.96	10.25	3.72
Dual Group B/D	0.80	2.07	0.50	3.17	8.21	2.98
Group C	51.02	132.14	31.81	41.81	108.28	39.26
Dual Group C/D	41.90	108.52	26.12	38.22	98.98	35.89
Group D	50.56	130.94	31.52	18.89	48.92	17.74
Not Rated	0.73	1.89	0.46	0.45	1.16	0.42
Totals =	160.37	415.36	100.00	106.49	275.80	100.00

2.2 Climate

Weather stations provide useful information for developing a general understanding of climatic conditions in a watershed. The most recent climate data from a weather station in close proximity to the Medicine Creek and Little Medicine Creek watersheds were measured at the National Weather Service's Princeton Weather Station in Mercer County. Climate normals are three-decade averages of climatological variables, including temperature and precipitation, produced by the National Centers for Environmental Information every 10 years (NOAA 2018). The monthly precipitation and temperature normals calculated from this station are derived from weather data collected during the 30-year period of 1981 through 2010. Of the various climatic factors, precipitation is especially important as it is related to stream flow and runoff events that can influence certain pollutant sources. Table 2 presents the 30-year monthly climate normals from the Princeton Weather Station for both temperature (Temp) and precipitation (PPTN). Figures 3 and 4 further summarize these data.

Table 2. 30-year monthly climate normals at the Princeton Weather Station

Month	Total PPTN Normal		Mean Max Temp		Mean Min Temp	
	in	mm	ºF	ºC	ºF	ºC
January	0.87	22.0	35.6	2.0	16.6	-8.6
February	1.26	32.0	40.6	4.8	20.0	-6.7
March	2.24	56.8	53.1	11.7	30.7	-0.7
April	3.93	99.8	64.5	18.1	41.6	5.3
May	4.98	126.4	73.7	23.2	52.5	11.4
June	4.86	123.4	82.5	28.1	62.4	16.9
July	5.22	132.5	87.2	30.7	67.0	19.4
August	3.88	98.5	86.4	30.2	64.8	18.2
September	3.34	84.8	78.5	25.8	54.6	12.6
October	3.18	80.7	66.6	19.2	43.4	6.3
November	2.09	53.0	52.0	11.1	31.3	-0.4
December	1.55	39.3	38.1	3.4	19.7	-6.8
Total PPTN & Avg Temp =	37.4	949.2	63.2	17.4	42.1	5.6

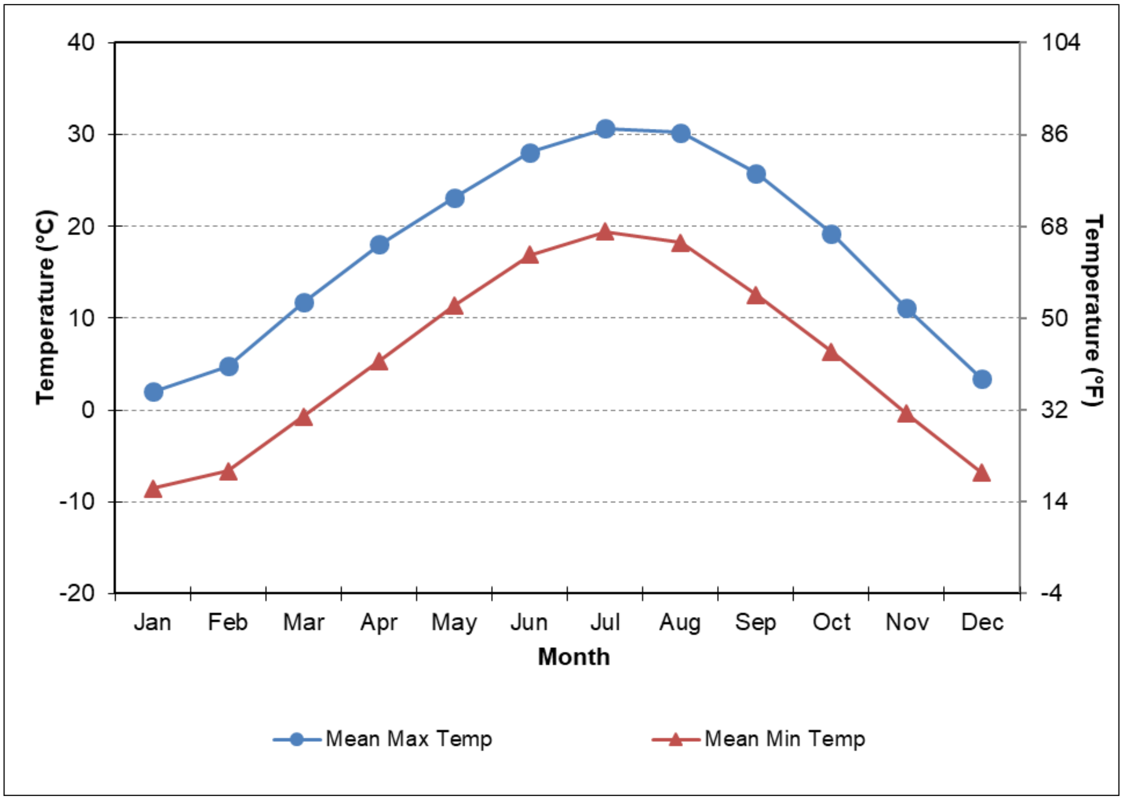

Figure 3. Monthly minimum and maximum temperature normals – Princeton weather station

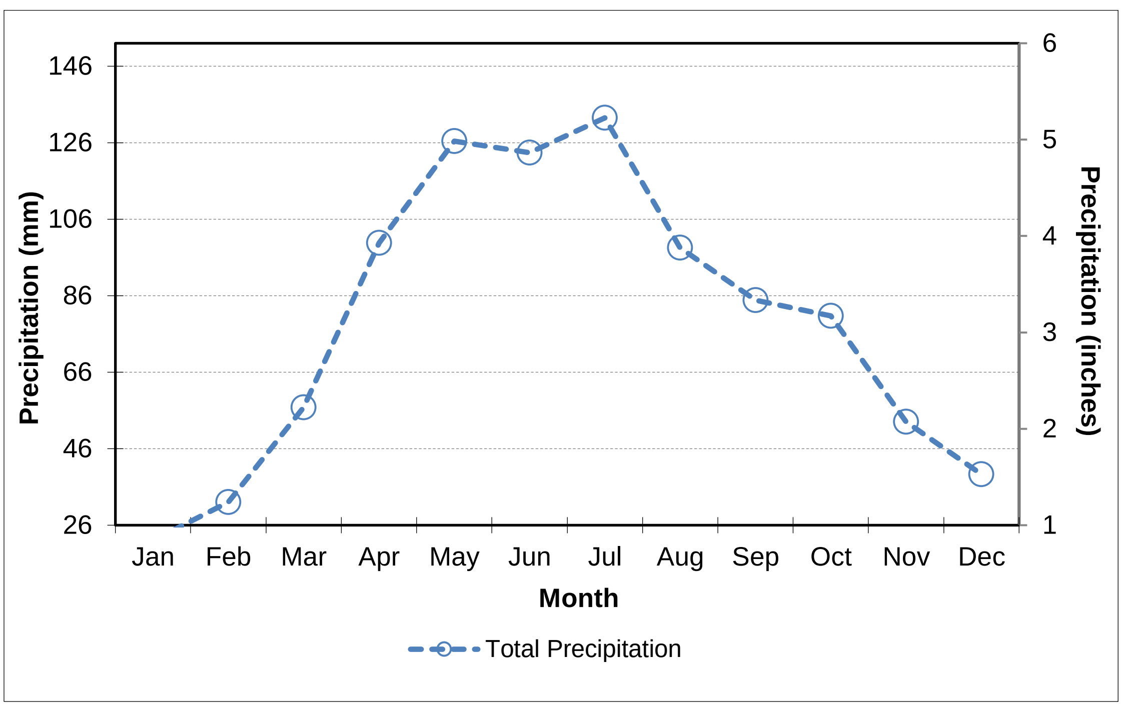

Figure 4. Monthly precipitation normals – Princeton Weather Station

2.3 Population

State and county population estimates are readily available from the U.S. Census Bureau's 2010 census. An estimate of the population within the Medicine Creek and Little Medicine Creek watersheds can be determined using U.S. Census Bureau census block data. Population estimates for these watersheds and the portions of these watersheds specifically within Missouri are presented in Table 3. As shown in Table 3, both watersheds have experienced moderate declines in population since 1990. As of the 2010 census, the U.S. Census Bureau has not classified any portions of these watersheds as being an "urban area." Such a designation is one criterion used for determining if a municipality is subject to small municipal separate storm sewer system permit regulations. At the time of this writing, no entities in the Medicine Creek or Little Medicine Creek watersheds are subject to such regulations.

Table 3. Population estimates for the Medicine Creek and Little Medicine Creek watersheds

Watershed	Total Population (includes Iowa)	Missouri Population Data								
		Municipal			Rural			Total		
	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Medicine Creek WBID 619	1,561	375	582	459	623	456	399	998	1,038	858
Little Medicine Creek WBID 623	586	329	304	290	300	325	294	629	598	584

Population estimates for the Medicine Creek and Little Medicine Creek watersheds were derived using Geographic Information System (GIS) software and superimposing the watershed boundaries over a map of census blocks (Figure 5). Wherever the centroid of a census block fell within a watershed boundary, the entire population of the census block was included in the total. If the centroid of the census block was outside the boundary, then the population of the entire block was excluded. Using a similar method, the municipal population was estimated by superimposing municipal areas over the map of census blocks. The rural population was calculated as the difference of the municipal population from the total population.

In 2014, EPA completed a separate population analysis based on 12-digit HUC subwatersheds for purposes unrelated to this TMDL. They used demographic and census block data, and a web-based tool called EJSCREEN to determine areas of Missouri having potential Environmental Justice concerns. EPA defines Environmental Justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (USEPA 2014a). Environmental Justice communities may qualify for financial and strategic assistance for addressing environmental and public health issues. From this analysis, EPA determined that none of the 12-digit HUC watersheds that comprise the Medicine Creek or Little Medicine Creek watersheds have potential Environmental Justice concerns.

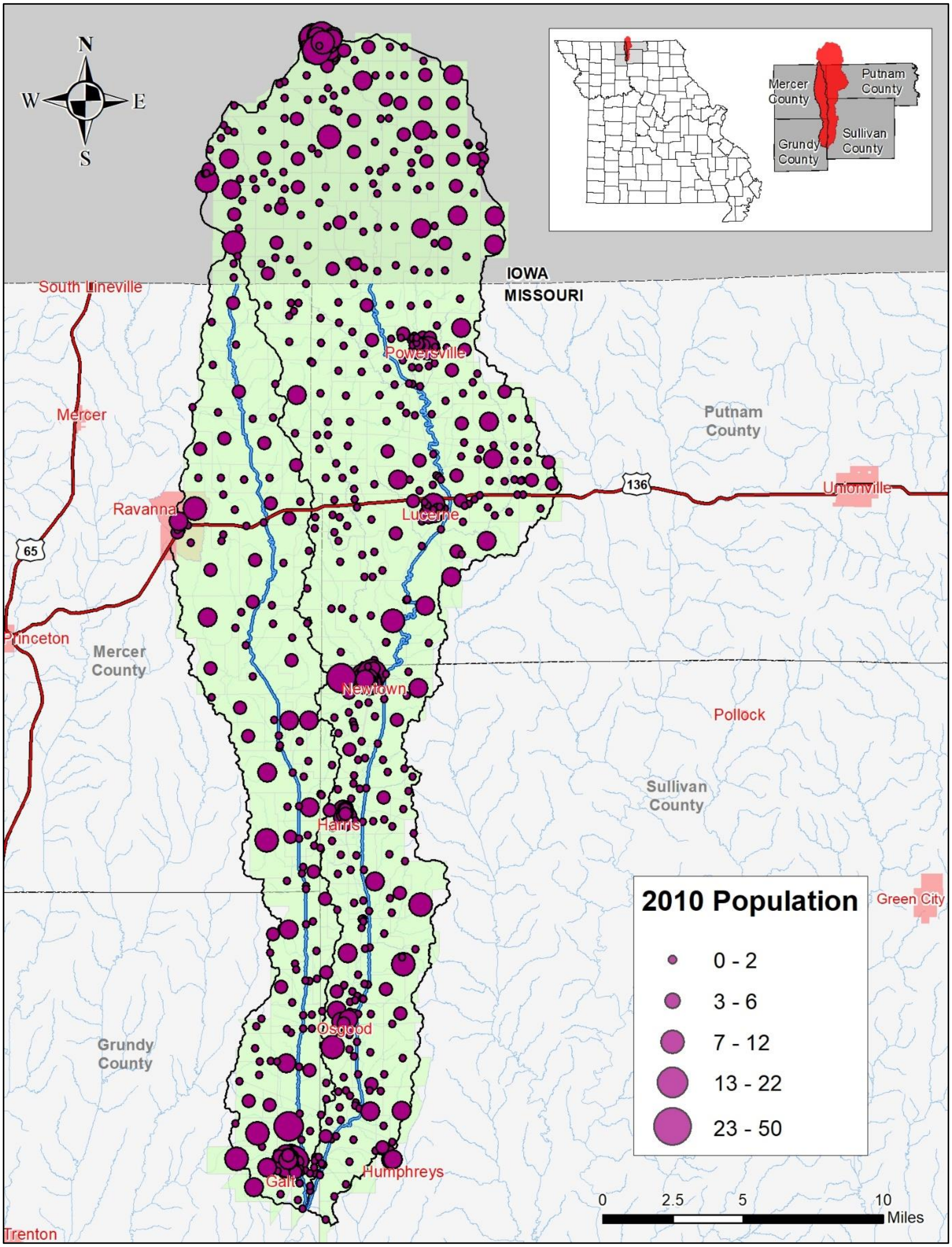

Figure 5. Census block populations in the Medicine and Little Medicine watersheds

2.4 Land Cover

A land cover analysis was completed using the 2011 National Land Cover Database published by USGS (Homer et al. 2015). Land cover information for the Medicine Creek and Little Medicine Creek watersheds is summarized in Table 4. Figure 6 depicts the distribution of the land coverage throughout these watersheds. Land coverage types associated with agricultural land uses, such as cultivated crops and grassland areas for livestock grazing, account for approximately 76 percent of each watershed.

Table 4. Land cover in the Medicine Creek and Little Medicine Creek watersheds

Land Cover Type	Medicine Creek Watershed		Little Medicine Creek Watershed	
	Area mi^2 (km^2)	Percent (%)	Area mi^2 (km^2)	Percent (%)
Developed, High Intensity	0.05 (0.12)	0.02	0.05 (0.12)	0.05
Developed, Medium Intensity	0.20 (0.51)	0.09	0.18 (0.46)	0.17
Developed, Low Intensity	2.25 (5.82)	0.95	0.94 (2.43)	0.88
Developed, Open Space	7.39 (19.14)	3.14	3.01 (7.79)	2.80
Barren Land	0.00 (0.00)	0.00	0.00 (0.00)	0.00
Cultivated Crops	43.01 (111.39)	18.26	17.21 (44.57)	15.98
Grassland and Pasture	137.08 (355.03)	58.20	65.07 (168.53)	60.42
Forest	40.02 (103.65)	16.99	18.43 (47.73)	17.11
Wetlands	4.50 (11.65)	1.91	2.17 (5.62)	2.01
Open Water	1.02 (2.64)	0.43	0.62 (1.60)	0.57
Totals =	235.53 (609.95)	100.00	107.68 (278.85)	100.00

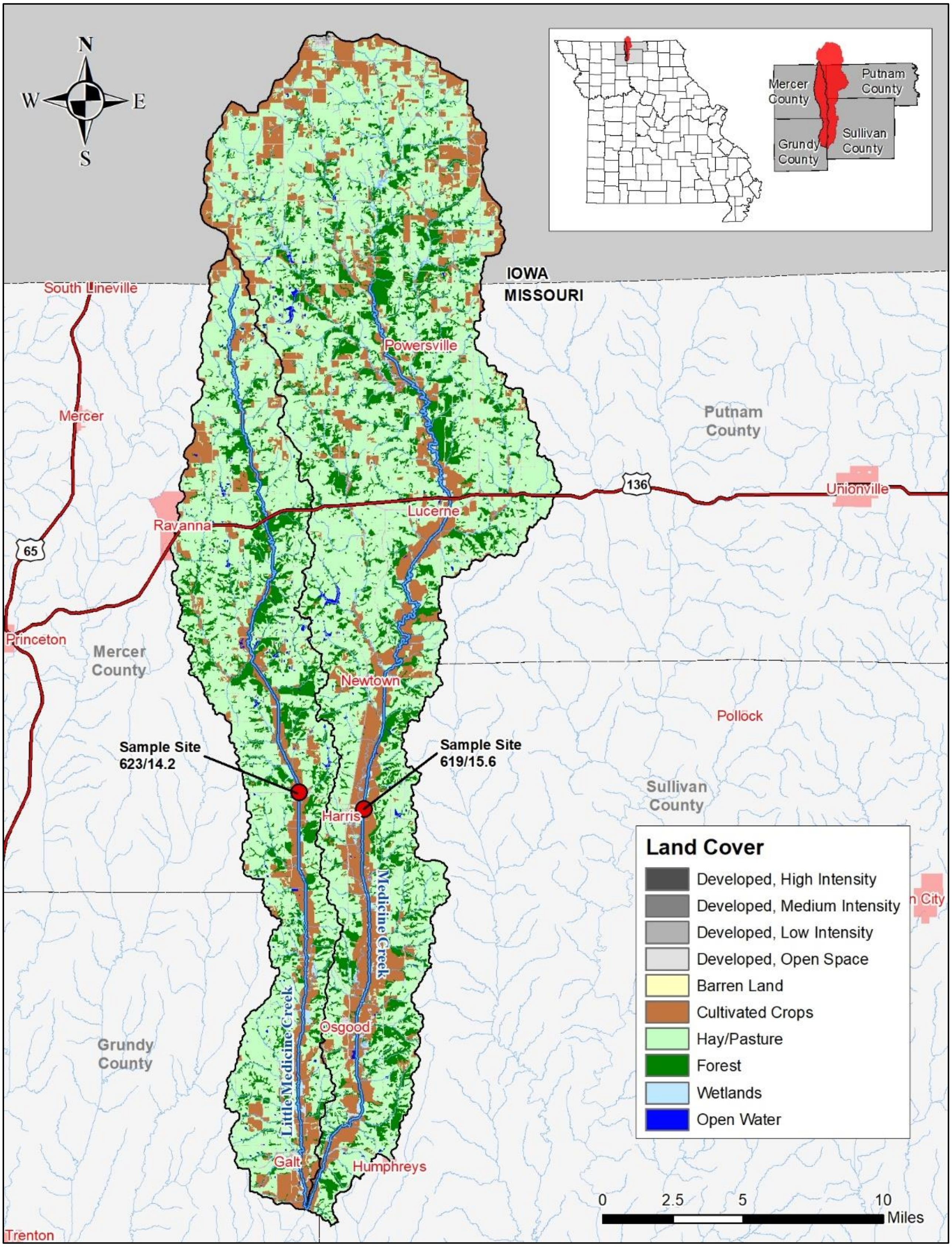

Figure 6. Land Cover in the Medicine Creek and Little Medicine Creek watersheds

3. Applicable Water Quality Standards

The purpose of developing a TMDL is to identify the maximum pollutant loading that a water body can assimilate and still attain and maintain water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). Water quality standards consist of three major components: designated uses, water quality criteria, and an antidegradation policy.

Per federal regulations at 40 CFR §131.10, the designated uses and criteria to protect those uses assigned to a water body shall provide for the attainment and maintenance of the water quality standards of downstream waters. The components of Missouri's Water Quality Standards discussed in this section meet these requirements and are approved by EPA. It is not the purview of a TMDL to revise existing water quality standards. In the event that future water quality monitoring demonstrates that existing water quality standards are not protective of downstream uses, the Clean Water Act provides means to address the situation. Such means are described in EPA's Water Quality Handbook.[10]

3.1 Designated Uses

Designated uses are the uses for a water body defined in Missouri's Water Quality Standards at 10 CSR 20-7.031(1)(C) and assigned per 10 CSR 20-7.031(2) and Table H.[11] These uses must be maintained in accordance with the federal Clean Water Act. The following designated uses have been assigned to the impaired water bodies and are reflected in the Missouri Use Designation Dataset as described at 10 CSR 20-7.031(2)(E):

- Irrigation;
- Livestock and wildlife protection;
- Human health protection;
- Protection and propagation of fish, shellfish and wildlife – warm water habitat;
- Whole body contact recreation category B; and
- Secondary contact recreation.

For Medicine Creek and Little Medicine Creek, the whole body contact recreation category B use is impaired due to high *E. coli* concentrations. Whole body contact recreation includes activities involving direct human contact with waters of the state to the point of complete body submergence (40 CFR 20-7.031(1)(C)2.A.). During such activities, such as swimming, accidental ingestion of the water may occur and there is direct contact to sensitive body organs, such as the eyes, ears and nose. Category A applies to waters that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreation uses by the public (10 CSR 20-7.031(1)(C)2.A.(I)). Category B applies to waters designated for whole body contact recreation not contained within category A (10 CSR 20-7.031(1)(C)2.A.(II)). Secondary contact recreation, which includes activities such as boating, fishing and wading, is not impaired. Secondary contact recreation includes activities that

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[10] https://www.epa.gov/wqs-tech/water-quality-standards-handbook

[11] The terminology used for naming designated uses varies from what is presented in the text of 10 CSR 20-7.031 and what is presented in Table H. The terminology utilized in the text of the water quality standards rule is presented here.

may result in contact with the water that is either incidental or accidental and the probability of ingesting appreciable quantities of water is minimal (10 CSR 20-7.031(1)(C)2.B.).

3.2 Water Quality Criteria

Water quality criteria are limits on certain chemicals or conditions in a water body to protect particular designated uses. Water quality criteria can be expressed as specific numeric criteria or as general narrative statements. In Missouri's Water Quality Standards at 10 CSR 20-7.031(5)(C) and Table A1, specific numeric *E. coli* criteria are given to protect whole body contact recreation. *E. coli* are bacteria found in the intestines of humans and warm-blooded animals and are used as indicators of potential fecal contamination and risk of pathogen-induced illness to humans. For category B waters, the *E. coli* count during the recreational season (April through October) shall not exceed the geometric mean of 206 counts/100 mL of water. This criterion is also protective of the secondary contact recreation designated use. The *E. coli* criterion for the protection of secondary contact recreation is a recreational season geometric mean that does not exceed 1,134 counts/100 mL of water.

3.3 Antidegradation Policy

Missouri's Water Quality Standards include the EPA "three-tiered" approach to antidegradation and may be found at 10 CSR 20-7.031(3).

Tier 1 – Protects public health, existing instream water uses and a level of water quality necessary to maintain and protect existing uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 28, 1975, the date of EPA's first Water Quality Standards Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

Waters in which a pollutant is at, near, or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goals for Medicine Creek and Little Medicine Creek are to restore water quality to levels that meet the water quality standards.

4. Defining the Problem

The Department assesses a stream to be impaired for *E. coli* if the water quality criteria are exceeded in any of the last three years for which there is a minimum of five samples collected during the recreational season. This approach is detailed in the Department's 2016 Listing Methodology Document, which is available online at dnr.mo.gov/env/wpp/waterquality/303d/303d.htm. Per federal regulations at 40 CFR§130.7(c)(1), TMDLs are required for all waters included on a state's approved 303(d) list.

Table 5 and Figures 7 and 8 present summaries of recent recreational season *E. coli* data used for assessing water quality in Medicine Creek and Little Medicine Creek. Appendix A provides the individual *E. coli* measurements. These observed data are presented to illustrate the nature of the impairment, but were not used in the calculation of TMDL allocations. Observed data may be used to estimate pollutant reduction targets for targeting implementation activities and selecting appropriate best management practices. Reduction targets for Medicine Creek and Little Medicine Creek are presented in a supplemental TMDL implementation strategies document available online at dnr.mo.gov/env/wpp/tmdl/619-medicine-cr-623-little-medicine-cr-record.htm.

Table 5. Summary of available recreational season *E. coli* data

Water Body	Recreational Season	Number of Samples	Minimum (count/100mL)	Maximum (count/100mL)	Geometric Mean (count/100mL)
Medicine Creek WBID 619	2013	6	220	3,400	762
	2014	7	29	3,300	464
	2015	7	100	5,400	599
	2016	7	120	26,000	790
	2017	7	72	2,400	315
	2018	7	13	850	172
Little Medicine Creek WBID 623	2013	6	150	4,800	676
	2014	7	66	1,700	370
	2015	7	77	3,100	425
	2016	7	62	22,000	495
	2017	7	97	830	245
	2018	7	52	1,000	187

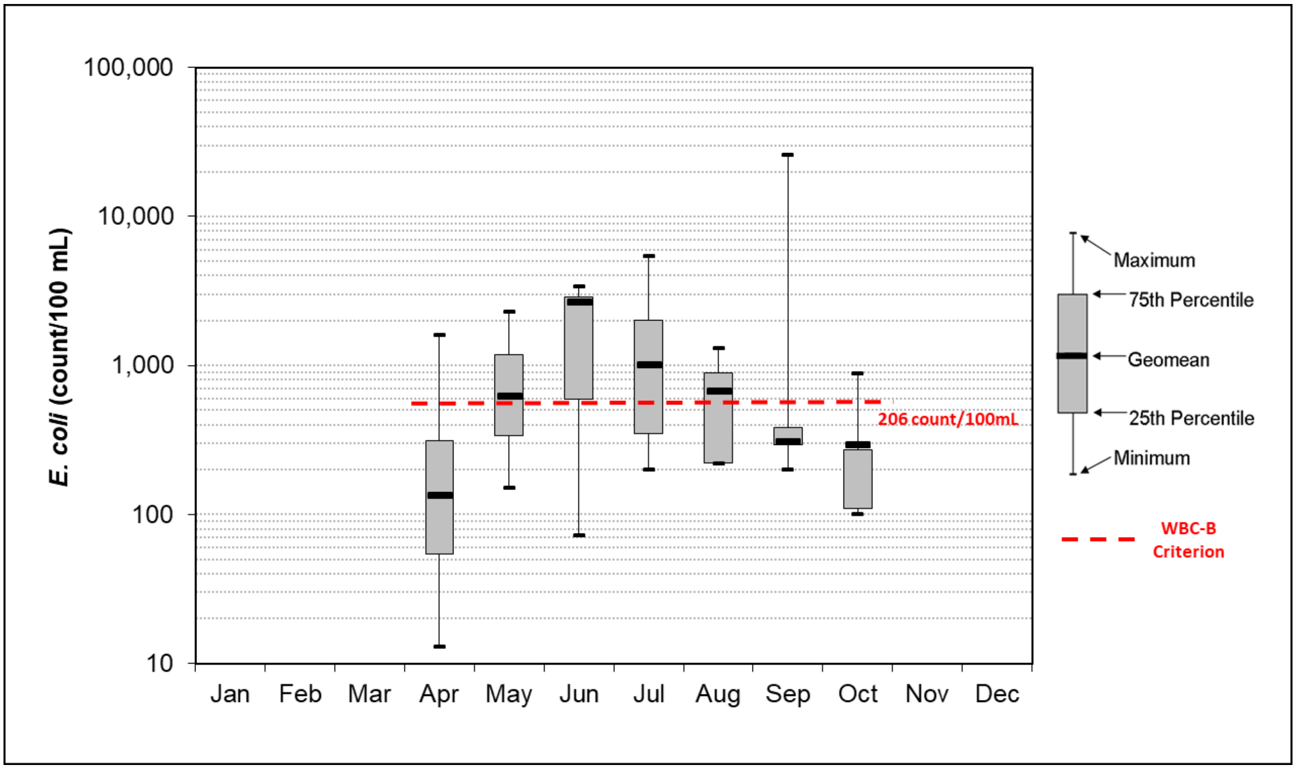

Figure 7. Summary of available recreational season *E. coli* data by month – Medicine Creek

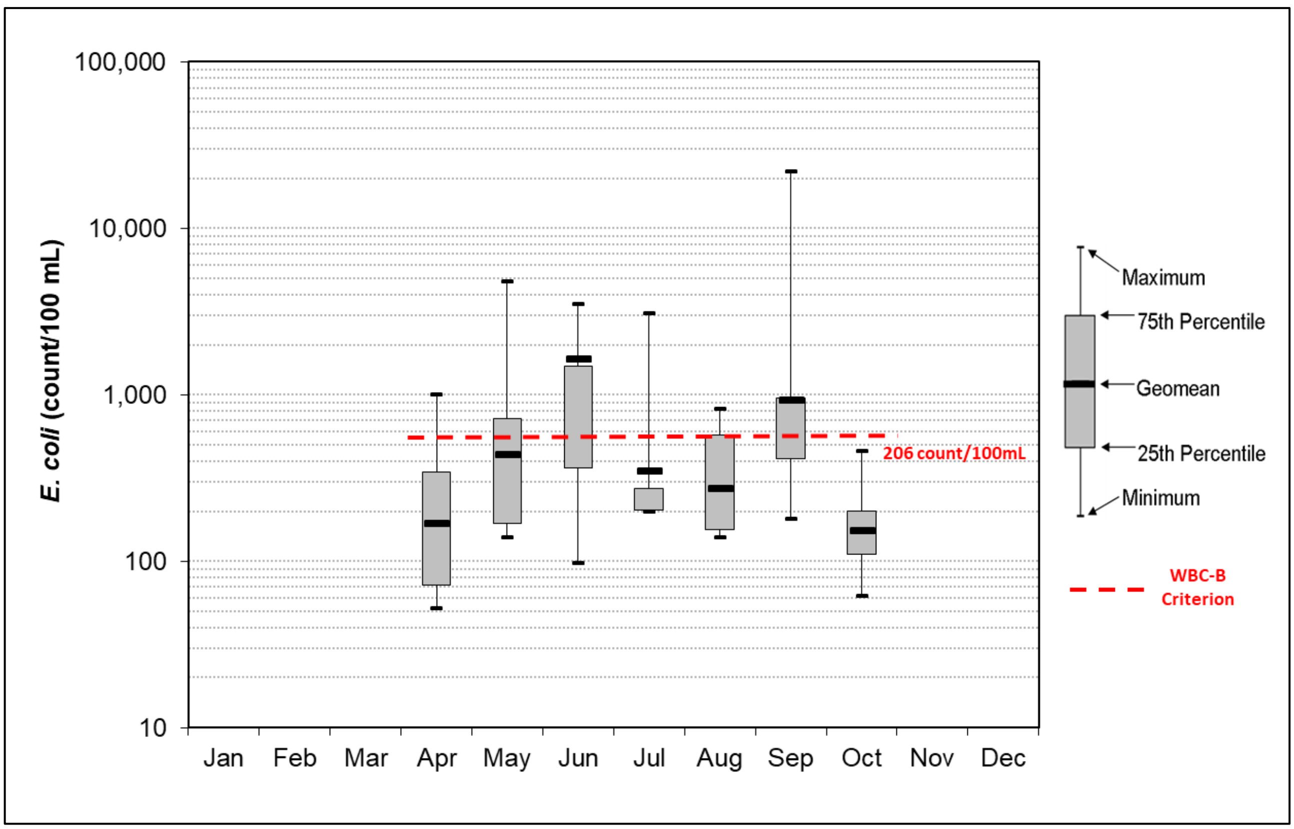

Figure 8. Summary of available recreational season *E. coli* data by month – Little Medicine Creek

5. Source Inventory and Assessment

Various sources may be contributing bacteria loads to the impaired water bodies. For this reason, a source inventory and assessment is included in this TMDL report to identify and characterize known, suspected, and potential sources of pollutant loading within the Medicine Creek and Little Medicine Creek watersheds. The potential sources of bacteria loading identified in this TMDL report are categorized and quantified to the extent that information is available. These sources are categorized as being either point (regulated) or nonpoint (unregulated).

5.1 Point Sources

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit program.[12] Point sources include any discernible, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, or conduit, by which pollutants are transported to a water body. Under this definition, permitted point sources include permitted municipal and domestic wastewater dischargers, site-specific permitted industrial, and non-domestic wastewater dischargers, concentrated animal feeding operations (CAFOs), municipal separate storm sewer systems, and general wastewater and stormwater permitted entites. In addition to these permitted sources, illicit straight pipe discharges, which are illegal and therefore unpermitted, are also point sources. In Iowa, point sources are regulated by the Iowa Department of Natural Resources and are presented in this document for informational purposes only. The locations of permitted outfalls in the Medicine Creek and Little Medicine Creek watersheds are presented in Figure 9. Some facilities have multiple permitted features with locations in both watersheds.

As of September 7, 2018, the Missouri portion of the Medicine Creek watershed contains 15 permitted entities. Two of these entities have site-specific permits for the discharge of treated municipal and domestic wastewater. Ten facilities are permitted CAFOs. One facility in the watershed has been issued a general wastewater permit. These types of permits are identifiable by their permit number having the prefix "MO-G." The remaining two entities in the watershed have general stormwater permits, which are identifiable by their permit numbers having the prefix "MO-R." There are no site-specific permitted industrial and non-domestic wastewater dischargers in the watershed, nor are there any permitted municipal separate storm sewer systems. In the Missouri portion of the Little Medicine Creek watershed, there are seven permitted entities. One is a site-specific permit for the discharge of treated municipal and domestic wastewater and the remaining six are CAFOs.

Permitted point sources are also present in the Iowa portions of these watersheds. In the Medicine Creek watershed, there is one municipal wastewater permit for the city of Allerton and one industrial wastewater permit for DairiConcepts, L.P., a food ingredient production facility. An additional eight facilities in the watershed are regulated animal feeding operations. In the Little Medicine Creek watershed, the only permitted entity is one regulated animal feeding operation. No municipal or industrial facilities are present in the Iowa portion of the Little Medicine Creek watershed. Missouri cannot impose TMDL wasteload allocations onto another state. Therefore in order to achieve Missouri water quality standards through the loading targets established by this TMDL, it must be assumed that any point source pollutant contributions from Iowa will be limited

[12] The Missouri State Operating system is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program. The NPDES program requires all point sources that discharge pollutants to waters of the United States to obtain a permit. Issued and proposed operating permits are available online at dnr.mo.gov/env/wpp/permits/index.html.

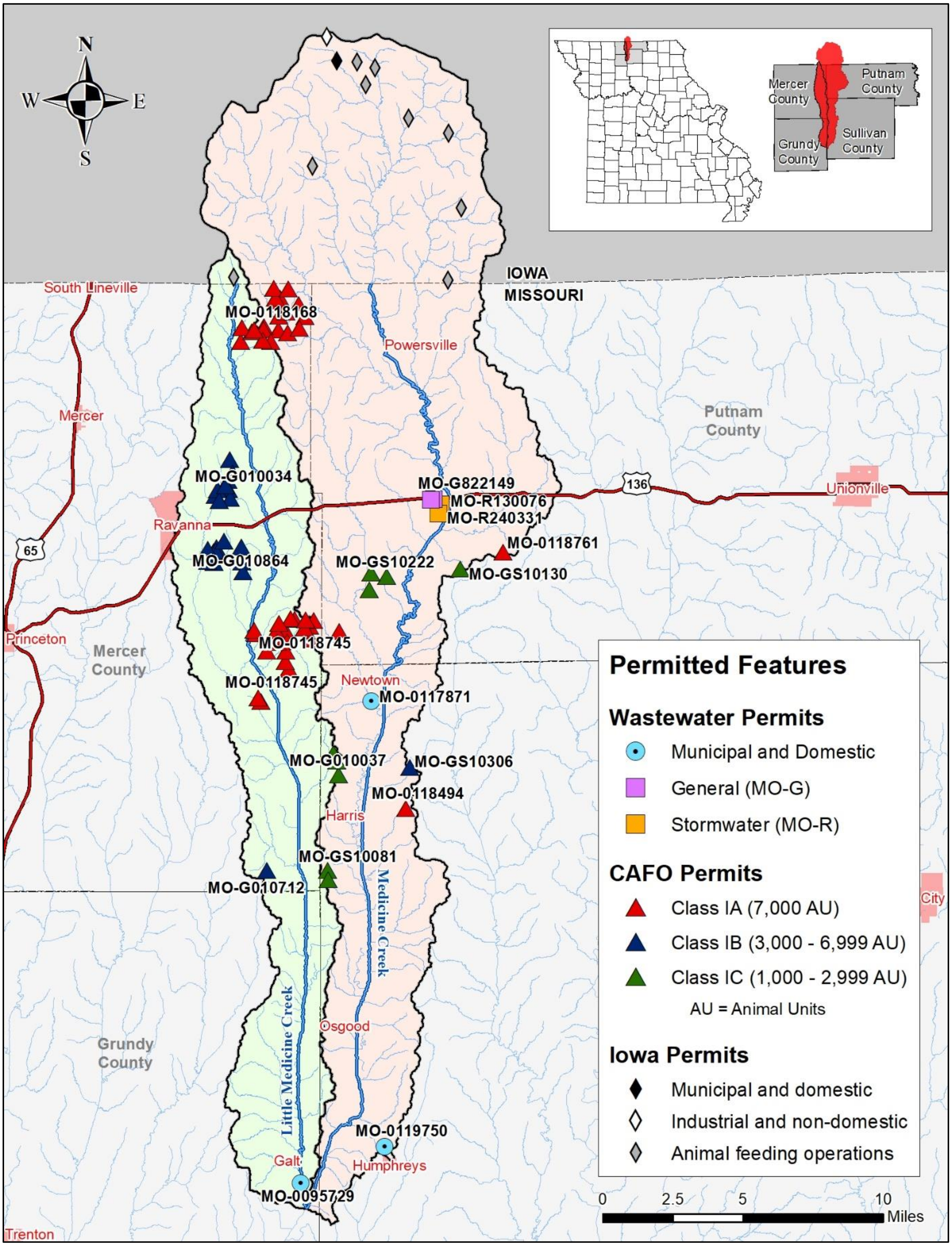

Figure 9. Permitted features in the Medicine Creek and Little Medicine Creek watersheds

to ensure Missouri's water quality standards will be met at the state line. This assumption is consistent with federal regulations at 40 CFR §131.10(b) that establishes that a state's water quality standards must provide for the attainment and maintenance of downstream water quality standards.

5.1.1 Municipal and Domestic Wastewater Discharge Permits

Dischargers of domestic wastewater include both publicly owned municipal wastewater treatment plants and non-municipal treatment facilities. Domestic wastewater is primarily household waste, including graywater and sewage. Untreated or inadequately treated discharges of domestic wastewater can be significant sources of bacteria to receiving waters (USEPA 1986). Influences of pollutant loading from domestic dischargers are typically most evident at low-flow conditions when stormwater influences are lower or nonexistent. Facilities equipped with disinfection technologies are capable of discharging *E. coli* at low concentrations and should not cause or contribute to bacteria impairments.

The Medicine Creek watershed contains two municipal wastewater facilities, the Humphreys Wastewater Treatment Facility and the Newtown Wastewater Treatment Facility (Table 6). Both facilities are three-cell lagoon systems and discharge intermittently through controlled discharges initiated by the operator. Although neither facility currently disinfects its effluent, numeric *E. coli* limits are specified in their operating permits and schedules of compliance for meeting disinfection requirements have been issued. Final *E. coli* effluent limits for the Humphreys facility will become effective on February 1, 2023. For the Newtown facility, *E. coli* effluent limits became effective on September 1, 2013. Although discharge from these facilities is infrequent, available discharge monitoring report data from 2013 through 2017 do show occasional contributions of *E. coli* loading from these lagoons to their receiving surface waters. For this reason, both the Humphreys Wastewater Treatment Facility and the Newtown Wastewater Treatment Facility are potential sources of *E. coli* loading to Medicine Creek.

Table 6. Municipal wastewater dischargers in the Medicine and Little Medicine watersheds

Watershed	Facility Name*	Permit Number	Design Flow ft^3/s (m^3/s)	Actual Flow ft^3/s (m^3/s)	Disinfection	Expires[13] (Mo/Day/Year)
Medicine Cr. WBID 619	Humphreys WWTF	MO-0119750	0.020 (0.0005)	0.016 (0.0004)	None	01/31/2023
	Newtown WWTF	MO-0117871	0.039 (0.0011)	0.020 (0.0005)	None	03/31/2018
L. Medicine Cr. WBID 623	Galt WWTF	MO-0095729	0.062 (0.0017)	0.051 (0.0014)	None	06/30/2023

* WWTF = wastewater treatment facility

In the Little Medicine Creek watershed, the Galt Wastewater Treatment Facility is the only municipal wastewater discharger.This facility is a three-cell lagoon system and numeric *E. coli* effluent limits are specified in its operating permit. These limits were effective May 1, 2013.

[13] When a permit expires, a facility remains bound by the conditions of that expired permit until either the permit is terminated or a new permit is issued.

Discharge monitoring report data from the Galt facility indicates that discharges from the lagoon are infrequent, however violations due to *E. coli* concentrations exceeding specified permit limits have been noted. For this reason, the Galt Wastewater Treatment Facility is a potential contributor to the *E. coli* impairment in Little Medicine Creek. A new permit for the Galt facility was issued on February 1, 2019. The permit indicates that the facility operates using “controlled discharge,” which requires manual operation of gates and valves for initiating and stopping discharge. The permit states that effluent limitations and water quality standards shall not be violated at any time during a controlled dishcarge.

In addition to the direct discharges from domestic wastewater treatment facilities, potential bacteria contributions may also occur from overflows occurring from the adjoining sanitary sewer system. A sanitary sewer system is a wastewater collection system designed to convey domestic, commercial, and industrial wastewater to the treatment facility. This system can include limited amounts of inflow and infiltration from groundwater and stormwater, but it is not designed to collect large amounts of runoff from precipitation events. Untreated or partially treated discharge from a sanitary sewer system is referred to as a sanitary sewer overflow. Sanitary sewer overflows can be caused by a variety of factors including blockages, line breaks, sewer defects, power failures, and vandalism. Sanitary sewer overflows can occur during either dry or wet weather and at any point in the collection system including overflows from manholes or backups into private residences. These types of discharges are unauthorized by the federal Clean Water Act. Occurrences of sanitary sewer overflows can result in elevated bacteria concentrations (USEPA 1996). Since 2013, no sanitary sewer overflows have been reported from the cities of Humphreys or Newton. In 2017, a single overflow event was reported from the City of Galt regarding a leaking valve on a force main. All wastewater from this incident was contained on site. Due to the infrequency of occurrence in these watersheds, sanitary sewer overflows are not considered a significant potential contributor of *E. coli* to Medicine Creek and Little Medicine Creek.

5.1.2 Site-Specific Industrial and Non-Domestic Wastewater Permits

Industrial and non-domestic facilities discharge wastewater resulting from non-sewage generating activities and are typically not expected to cause or contribute to bacteria impairments. At the time of this report, there are no permitted facilities of this type in the Medicine Creek and Little Medicine Creek watersheds.

5.1.3 CAFO Permits

CAFOs are typically animal feeding operations that confine and feed or maintain more than 1,000 animal units for 45 days or more during any 12-month period. Facilities with fewer animal units may be permitted as CAFOs voluntarily or if discharges occur or other water quality issues are discovered per 10 CSR 20-6.300. Animal wastes generated from CAFOs that are transported by stormwater runoff or by wastewater discharges can be a source of bacteria to water bodies (Rogers and Haines 2005). In Missouri, these types of facilities are permitted with either a site-specific permit or one of two available CAFO general permits (MO-G01 or MO-GS). CAFO facilities are present in both the Medicine Creek and Little Medicine Creek watersheds. Table 7 lists the CAFO facilities that are in these watersheds.

Table 7. CAFOs in the Medicine Creek and Little Medicine Creek watersheds

Facility Name	Permit Number	Permit Type	Watershed (WBID)	Expires (Mo/Day/Year)	Class[14]	Estimated Liquid Manure gal/yr (L/yr)
Smithfield Hog Production Somerset Farm	MO-0118168	Site-Specific	619 & 623	02/28/2022	IA	91,041,595 (344,629,926)
Smithfield Hog Production Locust Ridge	MO-0118494	Site-Specific	619	02/28/2022	IA	43,496,737 (164,653,060)
Smithfield Hog Production Badger/Wolf	MO-0118745	Site-Specific	619 & 623	02/28/2022	IA	105,627,522 (399,843,666)
MBM Terre Haute Farm	MO-0118761	Site-Specific	619	02/28/2022	IA	85,769,156 (324,671,573)
Smithfield Wade Webster Farm	MO-G010034	General	623	02/25/2023	IB	30,884,118 (116,909,104)
Smithfield Hog Production Overlook Farm	MO-G010037	General	619 & 623	02/25/2023	IC	14,670,152 (55,532,566)
Smithfield Summers Nursery	MO-G010712	General	623	02/25/2023	IB	4,160,762 (15,750,197)
Smithfield Peach-Perkins Farm	MO-G010864	General	623	02/25/2023	IB	35,848,015 (135,699,498)
Wise Enterprises, Inc.	MO-GS10081	State No-Discharge	619	1/28/2023	IC	1,000,000 (3,785,411)
James and Eddie Rhoades	MO-GS10130	State No-Discharge	619	1/28/2023	IC	2,937,575 (11,119,931)
Jack Wells	MO-GS10222	State No-Discharge	619	1/28/2023	IC	946,000 (3,580,999)
Ronald Faulkner Farm	MO-GS10306	State No-Discharge	619	1/28/2023	IB	10,315,084 (39,046,840)

Site-specific CAFO permits are written to address specific conditions for an individual facility, while general permits regulate potential discharges from multiple facilities conducting similar activities under generally similar conditions. The general permit types issued to CAFOs in Missouri are the MO-G01 CAFO permit and the MO-GS1 state no-discharge CAFO permit. Under the MO-G01 permit, CAFO facilities are not permitted to discharge manure or process wastewater, but exceptions are granted for situations where either a catastrophic storm event or a chronic wet weather event, as they are defined in the permit, overwhelms the facilities designed storage volume causing excess stormwater driven runoff and discharge.[15] Under the MO-GS1 permit, CAFO facilities are not allowed to discharge for any reason, without exception, and any discharge is a violation. CAFO facilities not operating as required by state operating permits may be significant sources of bacteria loading to surface waters. However, CAFO facilities operating in compliance with applicable permit requirements should not significantly contribute bacteria loading to surface waters via direct discharges.

[14] An operation's "class size" is a category that is based upon the total number of animal units confined at an operation. The Class IC, IB and IA are categories that start at 1,000, 3,000 and 7,000 animal units respectively, and are required by state regulation to obtain a permit. (1,000 animal units is equal to 2,500 swine; 100,000 broilers; 700 dairy cows; or 1,000 beef steers).

[15] Storage structures should be properly designed, constructed, operated, and maintained to contain all manure, litter, process wastewater plus the runoff and direct precipitation from the 25-year, 24-hour design storm event for the location of the CAFO.

Another potential source of bacteria loading from these operations is runoff from areas where animal wastes are land applied as fertilizer. Land applications occurring on areas under the control of a CAFO are subject to conditions found in the permit and the required nutrient management plan developed by the facility. For these reasons, land applications conducted by the CAFO facilities in compliance with permitted conditions should not be contributing significant bacteria loads to water bodies in the Medicine Creek and Little Medicine Creek watersheds. The Department does not regulate animal wastes from CAFOs that are sold as fertilizers and applied on areas not under the direct control of the CAFO. Likewise, the Department does not regulate manure fertilizers originating from locations outside the watershed that may be imported and applied to areas within the watershed. Any potential loading from such areas is considered nonpoint source pollution and is discussed in more detail in Section 5.2.1 of this document. Discussions pertaining to the potential bacteria contributions from animal feeding operations that do not require CAFO permits will also be found in Section 5.2.1.

5.1.4 Municipal Separate Storm Sewer System Permits

A municipal separate storm sewer system (MS4) is a stormwater conveyance system owned by a public entity that is not a combined sewer or part of a sewage treatment plant. Federal regulations issued in 1990 require discharges from such systems to be regulated by permits if a municipality's, or in some cases a county's, population is 100,000 or more. In 1999, new federal regulations required permits for discharges from small MS4s that are located within a U.S. Census Bureau defined urban area or have otherwise been designated as needing a permit by the permitting authority. At the time of this review, there are no permitted entities of this type in the Medicine Creek or Little Medicine Creek watersheds.

5.1.5 General Wastewater and Non-MS4 Stormwater Permits

General and stormwater permits are issued based on the type of activity occurring and are intended to be flexible enough to allow for ease and speed of issuance, while providing the required protection of water quality. General and stormwater permits are issued for activities similar enough to be covered by a single set of requirements and are designated with permit numbers beginning with "MO-G" or "MO-R," respectively. Table 8 presents a list of the general and non-MS4 stormwater permits in the Medicine Creek watershed, as of September 7, 2018. At the time of this report, no general or stormwater permits are present in the Little Medicine Creek watershed.

Table 8. General (MO-G) and stormwater (MO-R) permitted facilities in the Medicine watershed

Permit No.	Facility Name	Permit Type	Discharge Type	Expires (Mo/Day/Year)
MO-G822149	Lucerne Feed Mill	Land application of food processing wastewater	No discharge	05/22/2022
MO-R130076	Lucerne Feed Mill	Multiple industry stormwater permit	Stormwater	05/29/2018
MO-R240331	Dickerson Grain, Inc.	Agrichemical facilities	Stormwater	04/30/2019

For this TMDL, the Department assumes the general permitted activities described in Table 8, as well as any future general or stormwater permitted activities, will be conducted in compliance with all permit conditions, including monitoring and discharge limitations. It is expected that compliance with these permits will be protective of the applicable designated recreational uses within the watershed. For these reasons, general wastewater and stormwater permits are not expected to cause or contribute to the bacteria impairments of Medicine Creek and Little Medicine Creek. At any

time, if the Department determines that the water quality of streams in these watersheds are not being adequately protected, the Department may require the owner or operator of a permitted site to obtain a site-specific operating permit per 10 CSR 20-6.010(13)(C).

5.1.6 Illicit Straight Pipe Discharges

Illicit straight pipe discharges of domestic wastewater are also potential point sources of bacteria. These types of sewage discharges bypass treatment systems, such as a septic tank or a sanitary sewer, and discharge directly to a stream or an adjacent land area (Brown and Pitt 2004). Illicit straight pipe discharges are illegal and not authorized under the Clean Water Act. At present, there are no data about the presence or number of illicit straight pipe discharges in the Medicine Creek or Little Medicine Creek watersheds. For this reason, it is unknown to what significance straight pipe discharges contribute bacteria loads to surface waters in these watersheds. Due to the illegal nature of these discharges, any identified illicit straight pipe discharges must be eliminated.

5.2 Nonpoint Sources

Nonpoint source pollution refers to pollution coming from diffuse, non-permitted sources that typically cannot be identified as entering a water body at a single location. They include all other categories of pollution not classified as being from a point source. Nonpoint sources are exempt from Department permit regulations per state rules at 10 CSR 20-6.010(1)(B)1. These sources involve stormwater runoff and are minor or negligible under low-flow conditions. Typical nonpoint sources of pollution having the potential to influence water quality include various sources associated with runoff from agricultural lands and non-MS4 permitted urban areas, onsite wastewater treatment systems, natural background contributions, and areas having poor riparian corridor conditions.

5.2.1 Agricultural Runoff

Stormwater runoff from lands used for agricultural purposes is a potential source of bacteria loading to water bodies. As noted in Section 2.4 of this document, agricultural areas (cropland and pastureland) account for approximately 76 percent of the land area in each watershed. Activities associated with agricultural land uses that may contribute pathogen loading to these water bodies include manure fertilization and livestock production. Due to the large amount of area in the watershed available for agricultural land use practices, stormwater runoff from these areas is a potential contributor of *E. coli* to Medicine Creek and Little Medicine Creek.

Stormwater runoff from croplands or pasturelands fertilized with animal manure is a potential source of pathogens to surface waters. Application rates and timing vary by site depending upon a number of factors, including manure quality and soil fertility. In this region of the state, manure fertilizers (other than those from CAFOs) are most likely generated from cattle. Application rates and timing vary depending upon a number of factors, such as crop type, manure quality and soil need. However, a typical application is less than 10 tons per acre and can be as high as 20 tons per acre. When poultry litter is used, application rates are less and range from two to four tons per acre. (Zachary Erwin, University of Missouri Extension, email communication, March 16, 2016). Operations using nutrient management plans to guide manure applications and employing best management practices to reduce soil erosion will contribute smaller bacteria loads than those that do not.

In addition to manure spreading, bacteria may also be transported in runoff from pasturelands and low-density animal feeding operations. Although grazing areas are typically well vegetated, livestock concentrating near feeding and watering areas can create barren soil and thereby increase the possibility of surface erosion during a storm event (Sutton 1990). Additionally, livestock that are not excluded from streams may deposit manure directly into waterways.

Aside from the livestock present in permitted CAFOs, the numbers and types of livestock present in the Medicine Creek and Little Medicine Creek watersheds is unknown. An estimate of cattle numbers in the watershed was calculated using the available land cover data in Section 2.4 and county cattle population numbers provided in the U.S. Department of Agriculture's 2012 Census of Agriculture. The number of cattle per square mile of pastureland for each county in the watershed can be estimated from these data. Using these derived cattle densities, the number of cattle estimated within the Medicine Creek watershed is 18,410 (Table 9) and in the Little Medicine Creek watershed is about 5,650 (Table 10).[16] For beef cattle, the U.S. Department of Agriculture estimates that a 1,000-pound (453 kg) animal produces approximately 59.1 pounds (26.8 kilograms) of manure per day (USDA 1995). Another study found that 1 gram (0.002 pounds) of fresh manure from a cow on pasture contains a population of approximately 758,577 *E. coli* (Weaver et al. 2005).

Table 9. Cattle population estimates for pasture areas in the Medicine Creek watershed

County	Cattle No.	Pasture mi^2 (km^2)	Cattle Density No./mi^2 (No./km^2)	Watershed Pasture mi^2 (km^2)	Watershed Cattle No.
Grundy	16,167	190.6 (493.6)	85 (33)	0.1 (0.3)	10
Mercer	22,461	254.8 (659.9)	88 (34)	8.3 (21.4)	700
Putnam	48,851	284.7 (737.3)	172 (66)	53.7 (139.0)	9,200
Sullivan	40,638	393.6 (1,019.4)	103 (40)	29.8 (77.1)	3,000
Wayne (Iowa)	32,993	270.0 (699.2)	122 (47)	45.1 (116.8)	5,500
				Total =	18,410

Table 10. Cattle population estimates for pasture areas in the Little Medicine Creek watershed

County	Cattle No.	Pasture mi^2 (km^2)	Cattle Density No./mi^2 (No./km^2)	Watershed Pasture mi^2 (km^2)	Watershed Cattle No.
Grundy	16,167	190.6 (493.6)	85 (33)	14.2 (36.7)	1,200
Mercer	22,461	254.8 (659.9)	88 (34)	47.0 (121.7)	4,100
Putnam	48,851	284.7 (737.3)	172 (66)	0.0 (0.0)	0
Sullivan	40,638	393.6 (1,019.4)	103 (40)	3.3 (8.5)	300
Wayne (Iowa)	32,993	270.0 (699.2)	122 (47)	0.4 (1.0)	50
				Total =	5,650

[16] This analysis assumes all areas identified as hay or pasture are being used for cattle grazing and that cattle are evenly distributed among those areas. Additionally, although some animals may be confined in some areas, for purposes of this estimation the entire cattle population was assumed to be grazing on hay and pasture areas.

Other types of livestock may also be contributing bacteria loads in the Medicine Creek and Little Medicine Creek watersheds. Table 11 summarizes the county-level data for other livestock reported in the 2012 Census of Agriculture. There are no data available for which to estimate the number or distribution of these other animals in the watersheds or to estimate their potential pollutant contributions. Some of these livestock may be confined in unregulated animal feeding operations.

Table 11. Other livestock potentially present in the Medicine and Little Medicine watersheds

Livestock Type	Number of Animals per County				
	Grundy	Mercer	Putnam	Sullivan	Wayne (Iowa)
Sheep and lambs	303	733	1,282	645	1,576
Goats	242	231	116	127	1,105
Equine	810	459	496	737	1,080
Poultry (layers)	1,325	698	609	754	1,292

5.2.2 Unregulated Urban Runoff

In general, urban stormwater runoff may carry high levels of bacteria exceeding water quality criteria during and immediately after storm events (USEPA 1983). *E. coli* contaminated runoff can come from heavily paved areas and areas where soil erosion is common (Burton and Pitt 2002). Common sources of *E. coli* contamination in urban stormwater have been documented as originating from birds, dogs, cats, and rodents (Burton and Pitt 2002). Bacterial loads in urban runoff may also result from sanitary sewer overflows as described in Section 5.1.1 of this document.

In the Medicine Creek and Little Medicine Creek watersheds, areas of urban development account for a very small portion of these watersheds total area (Table 4). In both watersheds, areas categorized as low to high development comprise approximately 1 percent of the total land area and areas described as open space development account for approximately 3 percent. Degradation of water quality associated with imperviousness has been shown to first occur in a watershed at about 10 percent total imperviousness and to increase in severity as imperviousness increases (Arnold and Gibbons 1996; Schueler 1994). Due to the small amount of development in the watershed, urban stormwater runoff is not expected to be a major contributor of *E. coli* to the impaired water bodies. Population data presented in Table 4 indicate that major increases in development in this watershed are not likely to occur. However should substantial development occur in the future, best management practices and low impact development should be considered for mitigating the potential stormwater driven pollutant loading from impervious surfaces.

5.2.3 Onsite Wastewater Treatment Systems

Approximately 25 percent of homes in Missouri utilize onsite wastewater treatment systems, particularly in rural areas where public sewer systems may not be available (DHSS 2018). Onsite wastewater treatment systems treat domestic wastewater and disperse it to the property from where it is generated, such as a home septic system. When properly designed and maintained, such systems perform well and should not serve as a source of contamination to surface waters. However, onsite wastewater treatment systems can fail for a variety of reasons. When these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface water quality (Horsley & Witten 1996). Failing onsite wastewater treatment systems contribute bacteria loads to nearby streams under wet or dry weather conditions

through surface runoff and groundwater flows. Onsite wastewater treatment systems may contribute bacteria to water bodies directly or as component of stormwater runoff.

The exact number of onsite wastewater treatment systems in the Medicine Creek and Little Medicine Creek watersheds is unknown. EPA's online input data server for the Spreadsheet Tool for Estimating Pollutant Load (STEPL) provides estimates of septic system numbers by 12-digit HUC watersheds based on 1992 and 1998 data from the National Environmental Service Center (USEPA 2014b).[17] These STEPL derived estimates of septic system numbers are provided in Table 12. Due to no increase in the rural population of these watersheds since the 1990 census, this data is assumed to provide a reasonable estimate of actual septic system numbers.

Table 12 also provides statewide estimated failure rates from a study by the Electric Power Research Institute (EPRI 2000). The study suggests that in some parts of Missouri, up to 50 percent of onsite wastewater treatment systems may be failing. Due to these high failure rates, onsite wastewater treatment systems are potential sources of bacteria loading to surface waters in the Medicine Creek and Little Medicine Creek watersheds. However, the significance of such contributions is unknown.

Table 12. STEPL derived estimates of septic system numbers

Watershed	12-digit HUC	Subwatershed Name	No. of Systems	Population per System	Statewide Failure Rates
Medicine Creek WBID 619	102801030201	West Fork Medicine Creek	55	2	30% – 50%
	102801030202	Headwaters Medicine Creek	118	2	
	102801030203	Elm Branch	29	2	
	102801030204	Buckworth Creek-Medicine Creek	85	2	
	102801030205	Barber Creek	40	2	
	102801030206	Long Branch-Medicine Creek	42	2	
	102801030207	Hooton Creek-Medicine Creek	144	2	
Little Medicine Creek WBID 623	102801030101	Upper Little Medicine Creek	96	2	
	102801030102	Middle Little Medicine Creek	44	2	
	102801030103	Lower Little Medicine Creek	63	2	

5.2.4 Natural Background Contributions

Wildlife such as deer, waterfowl, raccoons, rodents, and other animals contribute to the natural background concentrations of *E. coli* that may be found in a water body. Such contributions may be a component of agricultural stormwater runoff, urban stormwater runoff, or runoff originating from other land coverage types as described in Table 5 of this report. While typical wildlife populations are not expected to cause or contribute to water body impairments, large congregations of animals, such as migrating Canada geese, have been found to contribute significant bacteria loads in some waters (Ishii et al. 2007). Although watershed specific information is lacking, the Missouri Department of Conservation estimates the statewide resident Canada goose population to be approximately 55,000 birds (MDC 2016a). The Department of Conservation also maintains deer harvesting data by county, which provides a general idea of the amount of deer that may be present

[17] The National Environmental Services Center is located at West Virginia University and maintains a clearinghouse for information related to, among other things, onsite wastewater treatment systems. Available URL: www.nesc.wvu.edu/

in an area. The Department of Conservation harvesting report for the 2015 through 2016 deer season noted that simulated statewide deer population values were approximately 75 percent greater than the number harvested (MDC 2016b). Table 13 provides deer harvest data for the 2016 through 2107 hunting season.

Table 13. County deer harvest data for the 2016 – 2017 hunting season (MDC 2017)

County	No. of Deer Harvested
Grundy	1,537
Mercer	2,166
Putnam	2,440
Sullivan	2,593

Due to the lack of watershed specific data about potential bacteria contributions from wildlife, estimations of such contributions cannot be made. For purposes of this TMDL, wildlife contributions are considered in the total nonpoint source load as part of the established load allocation. Pollutant reductions from wildlife sources are not expected to be necessary to achieve the loading targets established in this TMDL. Implementation activities should focus on pollutant reductions from anthropogenic sources.

5.2.5 Riparian Corridor Conditions

Riparian corridor conditions have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal, and assimilation of pollutants in runoff. Therefore, a stream with good riparian cover is often better able to mitigate the impacts of high pollutant loads than a stream with poor or no riparian cover. Table 14 presents land cover calculations for the riparian corridors within the Medicine Creek and Little Medicine Creek watersheds. This analysis of the riparian corridor used the same land cover data provided in Section 2.4 of this document and the riparian area as being a 100-foot (30-meter) wide buffer along each side of all streams in the watershed that are included in the high resolution National Hydrography Dataset.[18] Streams bordered by land used for livestock grazing have an increased risk for bacterial contamination if animals are not excluded from the stream or if adequate buffers to reduce stormwater inputs are not implemented and maintained. Similarly, stream segments adjacent to cropland may also receive contaminated runoff if the riparian corridor is absent or in poor condition.

[18] The National Hydrography Dataset is digital surface water data for geographic information systems, or GIS, for use in general mapping and in the analysis of surface-water systems. Available URL: http://nhd.usgs.gov

Table 14. Land cover in the riparian corridors of the Medicine and Little Medicine watersheds

Land Cover Type	Medicine Creek Watershed Area			Little Medicine Creek Watershed Area		
	acres	hectares	Percent	acres	hectares	Percent
Developed, High Intensity	0.00	0.00	0.0%	0.00	0.00	0.0%
Developed, Medium Intensity	0.67	0.27	0.0%	2.00	0.80	0.0%
Developed, Low Intensity	72.05	29.15	0.5%	31.80	12.86	0.4%
Developed, Open Space	306.89	124.19	2.0%	151.22	61.19	1.8%
Barren Land	0.44	0.17	0.0%	0.00	0.00	0.0%
Cultivated Crops	2,380.65	963.41	15.2%	1,261.16	510.37	15.4%
Grassland and Pasture	5,677.09	2,297.44	36.3%	3,026.69	1,224.86	37.0%
Forest	5,593.71	2,263.69	35.8%	2,873.24	1,162.76	35.1%
Wetlands	1,367.45	553.38	8.8%	708.3	286.63	8.7%
Open Water	226.17	91.52	1.4%	126.76	51.29	1.5%
Total:	**15,625.12**	**6,323.22**	**100.0%**	**8,181.17**	**3,310.76**	**100.0%**

6. Numeric TMDL Targets and Modeling Approach

As noted in Section 3.2 of this document, Missouri's Water Quality Standards include specific numeric *E. coli* criteria for waters designated for whole body contact recreation. The *E. coli* concentration of 206 counts/100 mL, which is protective of the category B recreational use, will serve as the numeric target for TMDL development for Medicine Creek and Little Medicine Creek. The resulting TMDL is expressed using a load duration curve to depict bacteria loads for all possible flows. The area under the water quality criterion curve is the compliance zone for the water body. When the geometric mean of all measured loads is located under the load duration curve, then water quality standards are achieved. Although applied as a daily target for the purposes of a TMDL, *E. coli* criteria are expressed as geometric means in the Missouri Water Quality Standards. Fluctuations in instantaneous instream bacteria concentrations are expected and individual bacteria measurements greater than the applicable recreational use concentration do not necessarily indicate a violation of water quality standards.

The load duration curve approach is consistent with the Anacostia Ruling (*Friends of the Earth, Inc., et al v. EPA*, No 05-5010, April 25, 2006) and EPA guidance in response to this ruling (USEPA 2006; USEPA 2007a). EPA guidance recommends that all TMDLs and associated pollutant allocations be expressed in terms of daily time increments and suggests there is flexibility in how these daily increments may be expressed. This guidance indicates that where pollutant loads or water body flows are highly dynamic it may be appropriate to use a load duration curve approach, provided that such an approach "identifies the allowable daily pollutant load for any given day as a function of the flow occurring on that day" (USEPA 2006). In addition, for targets that are expressed as a concentration of a pollutant, it may be appropriate to use a table or graph to display individual daily loads over a range of flows as a product of a water quality criterion, stream flow, and a conversion factor (USEPA 2006).

The load duration curve approach is also useful in identifying and differentiating between storm-driven and steady-input sources. The load duration approach provides a visual representation of stream flow conditions under which bacteria criteria exceedances have occurred, reveal critical

conditions, and help quantify the level of reduction necessary to meet the surface water quality targets for instream bacteria concentrations (Cleland 2002; Cleland 2003).

To develop load duration curves for the impaired segments of Medicine Creek and Little Medicine Creek, the average daily flows measured from USGS gage 06900050, located on Medicine Creek near Laredo, were area corrected to represent flows at the outlet of each watershed. An additional discussion about the methods used to develop the bacteria load duration curve is presented in Appendix B.

7. Calculating Loading Capacity

A TMDL calculates the loading capacity of a water body and allocates that load among the various pollutant sources in the watershed. The loading capacity is the maximum pollutant load that a water body can assimilate and still meet water quality standards. It is equal to the sum of the wasteload allocation, load allocation and the margin of safety:

$$TMDL = LC = \sum WLA + \sum LA + MOS$$

where LC is the loading capacity, ∑WLA is the sum of the wasteload allocations, ∑LA is the sum of the load allocations, and MOS is the margin of safety.

According to 40 CFR 130.2(i), TMDLs can be expressed in terms of mass per unit time, toxicity, or other appropriate measures. For the pathogen impaired segments of Medicine Creek and Little Medicine Creek, the TMDLs are expressed as *E. coli* counts per day using load duration curves and are applicable during the recreational season when state bacteria criteria apply. Figures 10 and 11 present the load duration curves for Medicine Creek and Little Medicine Creek respectively. To develop the load duration curves, the numeric TMDL target is multiplied by flow to generate the maximum daily load at different flows.[19] The resulting load duration curves represent the streams' loading capacities during the recreational season over the range of flows estimated to occur in these water bodies. In each of the following figures, the y-axis describes bacteria loading as counts per day and the x-axis represents the frequency for which a particular flow is met or exceeded. Lower flows are equaled or exceeded more frequently than higher flows. The individually plotted monitoring data were calculated by converting each sample's *E. coli* concentration to a daily load using the area corrected daily flow for the sampling date. These observed loads are presented only to illustrate flow conditions under which excessive bacteria loading may be occurring and are not used in the calculations for loading capacity or allocations. The flow condition ranges and descriptions presented in these figures illustrate general base-flow and surface-runoff conditions consistent with EPA guidance about using load duration curves for TMDL development (USEPA 2007b). Tables 15 and 16 provide summaries of the TMDL loading capacities and allocations for selected flow exceedances from the load duration curves. Additional information in Tables 17 and 18 provide loading targets specific to the Missouri portion of the Medicine and Little Medicine Creek watersheds based on the proportion of the watershed areas not located in Iowa. Due to the extremely large numbers associated with bacteria loads, *E. coli* values are presented using scientific notation. Specific allocations for individual sources are discussed in Sections 8 and 9 of this report.

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[19] $\boldsymbol{Load}\left(\frac{\text{count}}{\text{time}}\right) = \boldsymbol{Concentration}\left(\frac{\text{count}}{\text{volume}}\right) * \boldsymbol{Flow}\left(\frac{\text{volume}}{\text{time}}\right)$

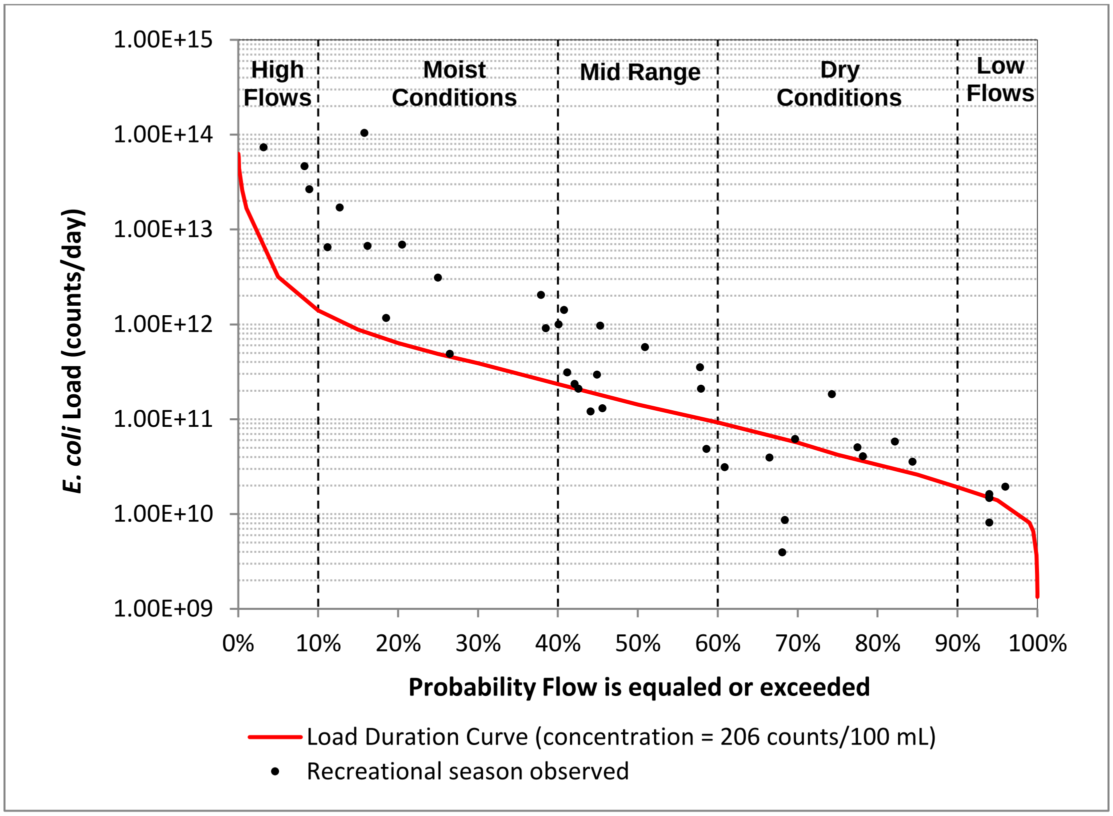

Figure 10. *E. coli* load duration curve for Medicine Creek, water body ID 619

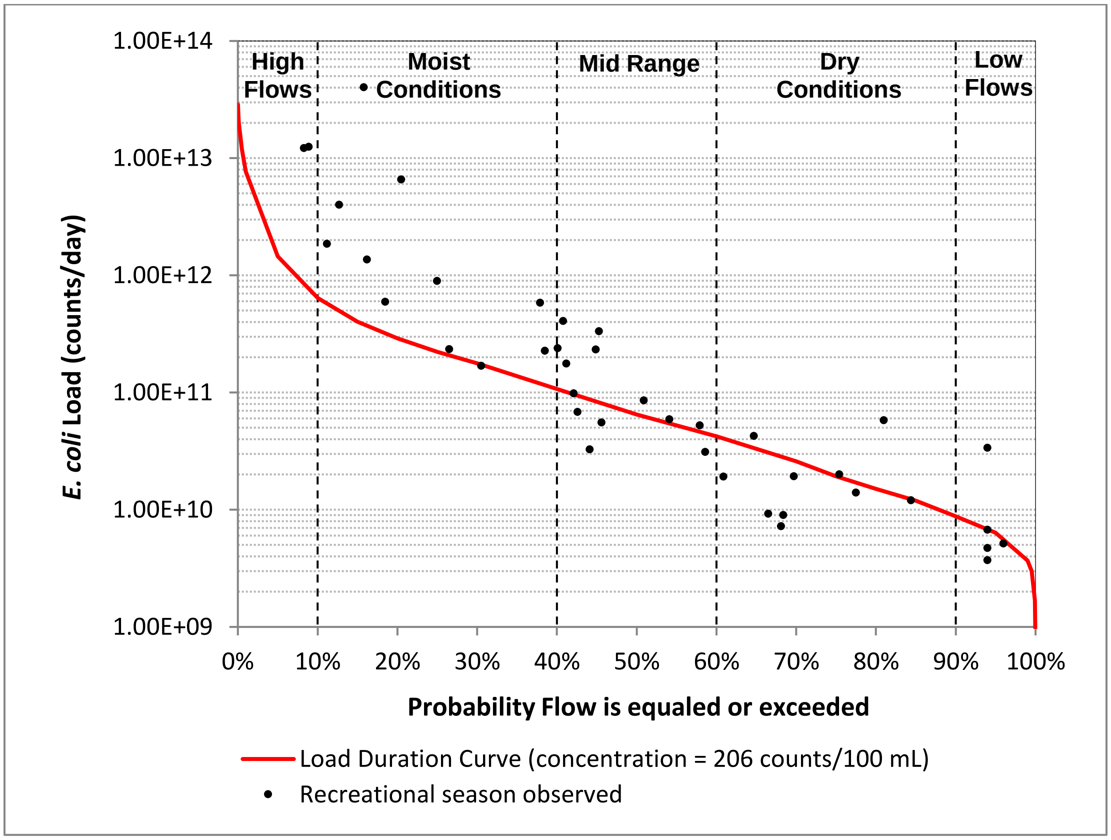

Figure 11. *E. coli* load duration curve for Little Medicine Creek, water body ID 623

Table 15. TMDL and allocation values for Medicine Creek at selected flows

Percent of time flow equaled or exceeded	Flow ft^3/s (m^3/s)	TMDL (counts/day)	∑WLA (counts/day)	∑LA (counts/day)	MOS (counts/day)
95	2.77 (0.07)	1.39E+10	2.97E+08	1.22E+10	1.39E+09
75	8.35 (0.23)	4.21E+10	2.97E+08	3.76E+10	4.21E+09
50	28.24 (0.79)	1.42E+11	2.97E+08	1.28E+11	1.42E+10
25	96.77 (2.74)	4.88E+11	2.97E+08	4.39E+11	4.88E+10
5	630.49 (17.85)	3.18E+12	2.97E+08	2.86E+12	3.18E+11

Table 16. TMDL and allocation values for Little Medicine Creek at selected flows

Percent of time flow equaled or exceeded	Flow ft^3/s (m^3/s)	TMDL (counts/day)	∑WLA (counts/day)	∑LA (counts/day)	MOS (counts/day)
95	1.26 (0.03)	6.37E+09	3.12E+08	5.42E+09	6.37E+08
75	3.82 (0.10)	1.92E+10	3.12E+08	1.70E+10	1.92E+09
50	12.91 (0.36)	6.51E+10	3.12E+08	5.82E+10	6.51E+09
25	44.24 (1.25)	2.23E+11	3.12E+08	2.00E+11	2.23E+10
5	288.23 (8.16)	1.45E+12	3.12E+08	1.31E+12	1.45E+11

Table 17. Loading values for Medicine Creek specific to Missouri watershed area

Percent of time flow equaled or exceeded	Flow ft^3/s (m^3/s)	TMDL (counts/day)	∑WLA (counts/day)	∑LA (counts/day)	MOS (counts/day)
95	2.77 (0.07)	9.56E+09	2.97E+08	8.31E+09	9.47E+08
75	8.35 (0.23)	2.88E+10	2.97E+08	2.56E+10	2.87E+09
50	28.24 (0.79)	9.72E+10	2.97E+08	8.72E+10	9.67E+09
25	96.77 (2.74)	3.33E+11	2.97E+08	2.99E+11	3.32E+10
5	630.49 (17.85)	2.17E+12	2.97E+08	1.95E+12	2.17E+11

Table 18. Loading values for Little Medicine Creek specific to Missouri watershed area

Percent of time flow equaled or exceeded	Flow ft^3/s (m^3/s)	TMDL (counts/day)	∑WLA (counts/day)	∑LA (counts/day)	MOS (counts/day)
95	1.26 (0.03)	6.31E+09	3.12E+08	5.36E+09	6.30E+08
75	3.82 (0.10)	1.90E+10	3.12E+08	1.68E+10	1.90E+09
50	12.91 (0.36)	6.44E+10	3.12E+08	5.76E+10	6.44E+09
25	44.24 (1.25)	2.20E+11	3.12E+08	1.98E+11	2.21E+10
5	288.23 (8.16)	1.44E+12	3.12E+08	1.30E+12	1.44E+11

8. Wasteload Allocation (Allowable Point Source Load)

The wasteload allocation is the allowable amount of the loading capacity assigned to existing or future point sources. This section discusses the rationale and approach for assigning *E. coli* wasteload allocations to point sources in the Medicine Creek and Little Medicine Creek watersheds as well as considerations given for future sources. Missouri cannot impose TMDL wasteload allocations onto another state, therefore wasteload allocation targets are calculated only for Missouri permitted facilities. Typically, point sources permit limits for a given pollutant are the most

stringent of either technology-based effluent limits or water quality-based effluent limits. Technology-based effluent limits are based upon the expected capability of a treatment method to reduce the pollutant to a certain concentration. Water quality-based effluent limits represent the most stringent concentration of a pollutant that a receiving stream can assimilate without violating applicable water quality standards at a specific location. Effluent limits or other permit conditions must be consistent with the assumptions and requirements of TMDL wasteload allocations per 40 CFR §122.44(d)(1)(vii)(B).

8.1 Municipal and Domestic Wastewater Discharges

The aggregated wasteload allocations for municipal and domestic wastewater dischargers in the Medicine Creek watershed is 2.97E+08 *E. coli* counts/day and is presented in Table 15. For Little Medicine Creek, the wasteload allocation is 3.12E+08 counts/day and is presented in Table 16. These allocations are based on the individual facility design flows presented in Table 6 and the *E. coli* criterion concentration of 206 counts/100 mL. Individual wasteload allocations calculated for municipal facilities in these watersheds are presented in Table 19. Actual flows that are less than the design flows and implementation of disinfection technologies may allow these facilities to discharge bacteria loads less than the calculated wasteload allocations. The wasteload allocations in this TMDL report do not authorize any facility to discharge bacteria at concentrations that exceed water quality standards, but may serve to accommodate additional facility loading due to population increases or expansions in service area. The wasteload allocations in this TMDL report are applicable at all flows during the recreational season and do not include loading that may result from sanitary sewer overflows. Sanitary sewer overflows are unpermitted discharges are not authorized under the Clean Water Act. For this reason, sanitary sewer overflows in the Medicine Creek and Little Medicine Creek watersheds are assigned wasteload allocations of zero at all flows.

Table 19. Wasteload allocations for municipal and domestic wastewater dischargers

Facility Name*	Permit Number	E. coli concentration (count/100mL)	WLA (count/day)
Galt WWTF	MO-0095729	206	3.12E+08
Humphreys WWTF	MO-0119750	206	1.01E+08
Newton WWTF	MO-0117871	206	1.97E+08

* WWTF = wastewater treatment facility

8.2 Site-Specific Permitted Industrial and Non-Domestic Wastewater Facilities

There are no site-specific permitted industrial and non-domestic wastewater facilities in the Medicine Creek and Little Medicine Creek watersheds. These types of facilities are not expected to significantly contribute to existing bacteria loads. For these reasons, site-specific permitted industrial and non-domestic wastewater facilities are not assigned a portion of the calculated wasteload allocation.

8.3 CAFOs

All CAFO facilities in the watershed are permitted as no-discharge facilities and store wastewater in lagoons and land apply accordingly. Assuming all permit conditions are met, including those

associated with land applications, CAFO facilities should not be contributing significant bacteria loads to surface waters. For this reason, the wasteload allocation for all CAFO facilities is zero at all flows. Animal wastes from CAFOs that are sold as fertilizers and applied on areas not under the direct control of a CAFO are not regulated by the Department and may potentially be nonpoint sources of bacteria to surface waters. Any loading from such applications should be made with considerations to the calculated TMDL load allocations (Section 9).

8.4 MS4 Permits

Currently there are no regulated MS4s in the Medicine Creek and Little Medicine Creek watersheds. Any *E. coli* contributions from urban stormwater runoff are included in the load allocations for nonpoint sources. If at any time an MS4 permit is required for stormwater discharges in these watersheds, then the appropriate portion of the load allocation may be assigned as a wasteload allocation.

8.5 General Wastewater and Non-MS4 Stormwater Permits

Activities permitted through general or stormwater permits are not generally expected to contribute significant bacteria loads to surface waters. The Department assumes that such activities conducted in compliance with all specified permit conditions, including land applications, monitoring and discharge limitations, will not contribute significant bacteria loads to surface waters. It is expected that compliance with these types of permits will be protective of the applicable designated recreational uses within the watershed. For this reason, these types of facilities are not assigned a specified portion of the calculated loading capacity. Wasteload allocations for these facilities are set at existing permit limits and conditions, which are assumed to be protective of all designated uses and result in bacteria loading at *de minimis* concentrations.

8.6 Illicit Straight Pipe Discharges

Illicit straight pipe discharges are illegal and are not permitted under the Clean Water Act. For this reason, illicit straight pipe discharges are assigned a wasteload allocation of zero. Any existing sources of this type must be eliminated.

8.7 Considerations for Future Point Sources

For these TMDLs, no specific portion of the loading capacity is allocated to a reserve capacity. However, the wasteload allocations presented in this TMDL report do not preclude the establishment of future point sources of bacteria in the watershed. Any future point sources should be evaluated against the TMDL, the range of flows with which any additional bacterial loading will affect, and any additional requirements associated with antidegradation. Per federal regulations at 40 CFR 122.4(a), no permit may be issued when the conditions of the permit do not provide for compliance with the applicable requirements of the Clean Water Act, or regulations promulgated under the Clean Water Act. Additionally, 40 CFR 122.4(i) states no permit may be issued to a new source or new discharger if the discharge from its construction or operation will cause or contribute to violation of water quality standards. Future general (MO-G) and stormwater (MO-R) permitted activities that do not actively generate bacteria and that operate in full compliance with permit conditions are not expected to contribute bacteria loads above *de minimis* levels and will not result in loading that exceeds the sum of the TMDL wasteload allocations. New domestic wastewater treatment systems that undergo antidegradation review will be required to disinfect their effluent during the recreational season and, therefore, are not expected to cause or contribute to the impairment. Decommissioning of onsite wastewater treatment systems and connecting to a

sewerage system for wastewater treatment will result in net pollutant reductions that are consistent with the goals of this TMDL. Wasteload allocations calculated for existing domestic wastewater dischargers based on design flow instead of actual flow will account for future discharge increases. Wasteload allocations between point sources may also be appropriately shifted between individual point sources where pollutant loading has shifted as long as the sum of the wasteload allocations is unchanged. In some instances a potential source may be re-categorized from a nonpoint source to a point source (e.g., newly designated MS4s or other permitted stormwater). If such a source's magnitude, character, and location remain unchanged, then the appropriate portion of the load allocation may be assigned as a wasteload allocation (USEPA 2012).

9. Load Allocation (Nonpoint Source Load)

The load allocation is the amount of the pollutant load that is assigned to existing and future nonpoint sources, as well as natural background contributions (40 CFR § 130.2(g)). Load allocations for these TMDLs are calculated as the remainder of the loading capacity after allocations to the wasteload allocation and margin of safety. Load allocations are presented in Tables 15 and 16. No portion of these load allocations are assigned to onsite wastewater treatment systems as such systems should not be contributing significant bacteria loads when operating as designed and properly maintained. For this reason, onsite wastewater treatment systems are assigned a load allocation of zero at all flows. For these TMDLs, load allocations also include any point source and nonpoint source contributions originating from Iowa. It is assumed that point source contributions from Iowa will be limited to ensure Missouri water quality standards are met at the state line.

10. Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems (CWA §303(d)(l)(C) and 40 C.F.R. §130.7(c)(l)). The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through two approaches:

- Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
- Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

For this TMDL, an explicit approach using 10 percent of the loading capacity has been reserved as a margin of safety. Additionally, bacteria decay rates were not applied and the direct recreational-season geometric mean was used for estimating the daily loading value as required by the Clean Water Act. These conservative assumptions serve as an additional implicit margin of safety. Should the municipal wastewater treatment facilities identified in this report install disinfection systems, then such technology may serve as an additional margin of safety since disinfection systems operate to eliminate nearly all present pathogens (target = 0 counts/100mL), rather than targeting a specific water quality criterion, resulting in very low *E. coli* concentrations.

11. Seasonal Variation

Federal regulations at 40 CFR §130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. Missouri's water quality criteria for the protection of recreational

uses are applicable only during the recreational season. The load duration curves for these TMDLs represent streamflow under all conditions as they were developed using numerous years of flow data collected during all seasons. For this reason, the *E. coli* targets and allocations found in this TMDL report will be protective throughout the recreational season including during flow conditions associated with storm-driven events, such as those associated with seasonal rain patterns when bacteria loading is more likely. The advantage of a load duration curve approach is that all flow conditions are considered and the constraints associated with using a single-flow critical condition are avoided.

12. Monitoring Plans

The Department often schedules and carries out post-TMDL monitoring approximately three years after the approval of the TMDL or in a reasonable timeframe following completion of permit compliance schedules and the application of new effluent limits. Data collected during such monitoring will be used for determining attainment or continued impairment of water quality standards as part of the Department's biennial water quality assessments required for Clean Water Act 305(b) and 303(d) reporting. The data derived from this monitoring may also be used for adjusting pollutant reduction goals and informing implementation activities. Furthermore, the Department will also routinely examine quality-assured water quality data collected by other local, state and federal entities in order to assess the effectiveness of TMDL implementation. In addition, certain quality-assured data collected by universities, municipalities, private companies, and volunteer groups may potentially be considered for monitoring water quality following TMDL implementation.

13. Reasonable Assurance

Section 303(d)(1)(C) of the federal Clean Water Act requires that TMDLs be established at a level necessary to implement applicable water quality standards. As part of the TMDL process, consideration must be given to the assurances that point and nonpoint source allocations will be achieved and water quality standards attained. Where TMDLs are developed for waters impaired by point sources only, reasonable assurance is provided through the NPDES permitting program. State operating permits requiring effluent and instream monitoring be reported to the Department should provide reasonable assurance that instream water quality standards will be met.

Where a TMDL is developed for waters impaired by both point and nonpoint sources, point source wasteload allocations must be stringent enough so that in conjunction with the water body's other loadings (i.e., nonpoint sources) water quality standards are met. Reasonable assurance that nonpoint sources will meet their allocated amount is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls, or best management practices within the watershed. If best management practices or other nonpoint source pollution controls allow for more stringent load allocations, then wasteload allocations can be less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs (40 CFR 130.2(i)). When a demonstration of nonpoint source reasonable assurance is developed for an impaired water body, additional pollutant allocations for point sources may be allowed provided water quality standards are still attained. If a demonstration of nonpoint source reasonable assurance does not exist, or it is determined that nonpoint source pollutant reduction plans, controls, or best management practices are not feasible, durable, or will not result in the required load reductions, then allocation of greater pollutant loading to point sources cannot occur.

A variety of grants and loans may be available to assist watershed stakeholders with developing and implementing watershed based plans, controls, and practices to meet the required wasteload and load allocations in the TMDL and demonstrate reasonable assurance. Information regarding potential funding sources and implementation actions addressing pollutant sources in the Medicine Creek and Little Medicine Creek watersheds is provided in the supplemental TMDL Implementation Strategies document at dnr.mo.gov/env/wpp/tmdl/619-medicine-cr-623-little-medicine-cr-record.htm.

14. Public Participation

EPA regulations at 40 CFR§130.7 require that TMDLs be subject to public review. A 45-day public notice period for this TMDL report was held from December 7, 2018 through January 22, 2019.

Groups that directly received notice of the public comment period for this TMDL include, but are not limited to:

- Missouri Clean Water Commission;
- Missouri Water Protection Forum;
- Missouri Department of Conservation;
- Iowa Department of Natural Resources;
- County soil and water conservation districts;
- County health departments;
- County commissions;
- Green Hills Regional Planning Commission;
- University of Missouri Extension;
- Missouri Coalition for the Environment;
- Stream Teams United;
- Stream Team volunteers living in or near the watershed;
- Affected permitted entities; and
- Missouri state legislators representing areas within the watershed.

In addition to those groups directly contacted about the public notice, this TMDL report and an implementation strategies document are posted on the Department's TMDL webpage at dnr.mo.gov/env/wpp/tmdl/619-medicine-cr-623-little-medicine-cr-record.htm. All comments received during this period and the Department's responses to those comments are also available at this location.

The Department also maintains an email distribution list for notifying subscribers of significant TMDL updates or activities, including public notices and comment periods. Those interested in subscribing to TMDL updates can submit their email address using the online form available at public.govdelivery.com/accounts/MODNR/subscriber/new?topic_id=MODNR_177.

15. Administrative Record and Supporting Documentation

The Department has an administrative record on file for the Medicine Creek and Little Medicine Creek *E. coli* TMDL. The record contains any plans, studies, data, and calculations on which the TMDL is based. It additionally includes the TMDL implementation strategies document, the public notice announcement, any public comments received, and the Department's responses to those comments. This information is available upon request to the Department at

dnr.mo.gov/sunshine-form.htm. Any request for information about this TMDL will be processed in accordance with Missouri's Sunshine Law (Chapter 610, RSMO) and the Department's administrative policies and procedures governing Sunshine Law requests. For more information about open record/Sunshine requests, please consult the Department's website at dnr.mo.gov/sunshinerequests.htm.

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Appendix A

Medicine Creek (WBID 619) and Little Medicine Creek (WBID 623) *E. coli* data

Water Body	Sampling Organization	Sample ID	Site Code	Sample Type	Date	E. coli (count/100ml)
Medicine Creek WBID 619	USGS	238791	619/15.6	Grab	4/9/2013	1,600
	USGS	238792	619/15.6	Grab	5/21/2013	2,300
	USGS	238793	619/15.6	Grab	6/26/2013	3,400
	USGS	238794	619/15.6	Grab	7/10/2013	230
	USGS	238795	619/15.6	Grab	8/14/2013	220
	USGS	238796	619/15.6	Grab	9/18/2013	310
	USGS	243999	619/15.6	Grab	4/9/2014	29
	USGS	244000	619/15.6	Grab	5/6/2014	150
	USGS	244001	619/15.6	Grab	6/11/2014	3,300
	USGS	244002	619/15.6	Grab	7/17/2014	860
	USGS	250996	619/15.6	Grab	8/20/2014	1,300
	USGS	250997	619/15.6	Grab	9/24/2014	330
	USGS	250998	619/15.6	Grab	10/8/2014	880
	USGS	255910	619/15.6	Grab	4/16/2015	130
	USGS	255914	619/15.6	Grab	5/13/2015	730
	USGS	255918	619/15.6	Grab	6/17/2015	1,700
	USGS	255921	619/15.6	Grab	7/28/2015	5,400
	USGS	255924	619/15.6	Grab	8/12/2015	1,100
	USGS	255927	619/15.6	Grab	9/1/2015	290
	USGS	255931	619/15.6	Grab	10/7/2015	100
	USGS	278472	619/15.6	Grab	4/6/2016	220
	USGS	278473	619/15.6	Grab	5/17/2016	1300
	USGS	278474	619/15.6	Grab	6/23/2016	1100
	USGS	278475	619/15.6	Grab	7/21/2016	700
	USGS	278476	619/15.6	Grab	8/23/2016	280
	USGS	278477	619/15.6	Grab	9/20/2016	26000
	USGS	278478	619/15.6	Grab	10/19/2016	120
	USGS	276390	619/15.6	Grab	4/13/2017	340
	USGS	276391	619/15.6	Grab	5/16/2017	210
	USGS	276392	619/15.6	Grab	6/6/2017	72
	USGS	276393	619/15.6	Grab	7/13/2017	2400
	USGS	276394	619/15.6	Grab	8/10/2017	230
	USGS	276395	619/15.6	Grab	9/28/2017	400
	USGS	276396	619/15.6	Grab	10/3/2017	270
	USGS	277407	619/15.6	Grab	4/12/2018	13.0
	USGS	277408	619/15.6	Grab	5/17/2018	850
	USGS	277409	619/15.6	Grab	6/6/2018	420
	USGS	277410	619/15.6	Grab	7/26/2018	200
	USGS	277411	619/15.6	Grab	8/21/2018	220
	USGS	277412	619/15.6	Grab	9/18/2018	200
	USGS	277413	619/15.6	Grab	10/24/2018	110

Water Body	Sampling Organization	Sample ID	Site Code	Sample Type	Date	E. coli (count/100ml)
Little Medicine Creek WBID 623	USGS	238835	623/14.2	Grab	4/9/2013	1,000
	USGS	238836	623/14.2	Grab	5/21/2013	4,800
	USGS	238837	623/14.2	Grab	6/26/2013	3,500
	USGS	238838	623/14.2	Grab	7/10/2013	210
	USGS	238839	623/14.2	Grab	8/14/2013	150
	USGS	238840	623/14.2	Grab	9/18/2013	180
	USGS	244011	623/14.2	Grab	4/9/2014	66
	USGS	244012	623/14.2	Grab	5/6/2014	140
	USGS	244013	623/14.2	Grab	6/11/2014	1,700
	USGS	244014	623/14.2	Grab	7/17/2014	280
	USGS	251011	623/14.2	Grab	8/20/2014	820
	USGS	251012	623/14.2	Grab	9/24/2014	570
	USGS	251013	623/14.2	Grab	10/8/2014	460
	USGS	255964	623/14.2	Grab	4/16/2015	77
	USGS	255968	623/14.2	Grab	5/13/2015	400
	USGS	255972	623/14.2	Grab	6/17/2015	760
	USGS	255975	623/14.2	Grab	7/28/2015	3,100
	USGS	255976	623/14.2	Grab	8/12/2015	690
	USGS	255978	623/14.2	Grab	9/1/2015	360
	USGS	255982	623/14.2	Grab	10/7/2015	140
	USGS	278498	623/14.2	Grab	4/6/2016	230
	USGS	278499	623/14.2	Grab	5/17/2016	820
	USGS	278500	623/14.2	Grab	6/23/2016	830
	USGS	278501	623/14.2	Grab	7/19/2016	200
	USGS	278502	623/14.2	Grab	8/23/2016	170
	USGS	278503	623/14.2	Grab	9/20/2016	22000
	USGS	278504	623/14.2	Grab	10/19/2016	62
	USGS	276418	623/14.2	Grab	4/13/2017	380
	USGS	276419	623/14.2	Grab	5/16/2017	150
	USGS	276420	623/14.2	Grab	6/6/2017	97
	USGS	276421	623/14.2	Grab	7/11/2017	260
	USGS	276422	623/14.2	Grab	8/8/2017	220
	USGS	276423	623/14.2	Grab	9/26/2017	830
	USGS	276424	623/14.2	Grab	10/3/2017	200
	USGS	277429	623/14.2	Grab	4/12/2018	52
	USGS	277430	623/14.2	Grab	5/15/2018	220
	USGS	277431	623/14.2	Grab	6/6/2018	230
	USGS	277432	623/14.2	Grab	7/26/2018	200
	USGS	277433	623/14.2	Grab	8/21/2018	140
	USGS	277434	623/14.2	Grab	9/20/2018	1000
	USGS	277435	623/14.2	Grab	10/24/2018	110

Appendix B

Development of Bacteria Load Duration Curves

Overview

The load duration curve approach was used to develop the TMDLs for impaired water body segments of Medicine Creek and Little Medicine Creek in northern Missouri. The load duration curve method allows for characterizing water quality concentrations (or water quality data) at different flow regimes and estimating the load allocations and wasteload allocations for each impaired segment. This method also provides a visual display of the relationship between stream flow and loading capacity. Using the duration curve framework, allowable loadings are easily presented.

Methodology

The load duration curve method requires a long-term time series of daily flows, numeric water quality targets, and sample bacteria data. Bacteria data from the impaired segment, along with the flow estimates for the same date, are plotted along with the load duration curve to assess when the water quality target may have been exceeded.

To develop a load duration curve, the average daily flow data from a gage or multiple gages that are representative of the impaired reach are used. The flow record should be of sufficient length to be able to calculate percentiles of flow. If a flow record for an impaired stream is not available, then flow data collected from a gage in a representative watershed may be used or a synthetic flow record from several gages can be developed. For the Medicine Creek and Little Medicine Creek TMDLs, flow estimates were area corrected using flows measured by USGS stream gage 06900050, located on Medicine Creek near Laredo, from November 14, 2000 through July 10, 2018. Average daily flow values were corrected based on the proportion of the area draining to the impaired stream's watershed to that draining to the flow gage (Table B1). Figures B1 and B2 present the flow duration curves developed for the impaired water body segments. These flows, in units of cubic feet per second, are then multiplied by the applicable water quality target (206 counts/100 mL) and a conversion factor of 24,465,715 in order to generate the allowable load in units of counts/day.[20] Despite the varying load, the targeted concentration is constant at all flow percentiles and reflects the static nature of the water quality standards.

Table B1. Information used for developing area corrected flow records

Location:	USGS 06900050	WBID 619	WBID 623
Drainage Area:	355 mi^2 (919.4 km^2)	235.3 mi^2 (609.4 km^2)	107.6 mi^2 (278.6 km^2)
Correction Factor:	--	0.6628	0.3030

[20] $Load\ \left(\frac{\text{count}}{\text{day}}\right) = \left[Target\left(\frac{\text{count}}{\text{100ml}}\right)\right] * \left[Flow\ \left(\frac{feet^3}{s}\right)\right] * [Conversion\ Factor]$

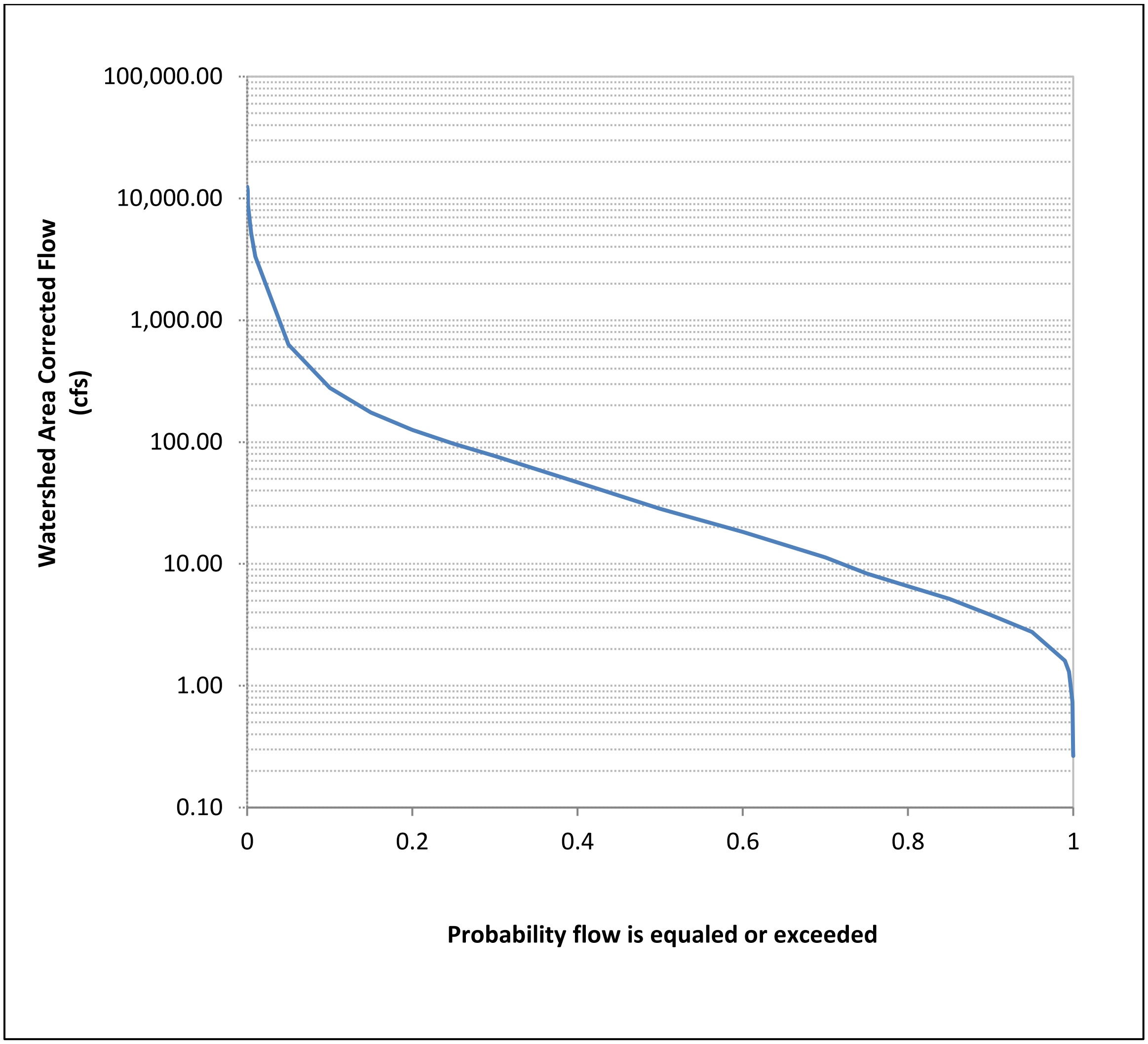

Figure B1. Medicine Creek, WBID 619, flow duration curve

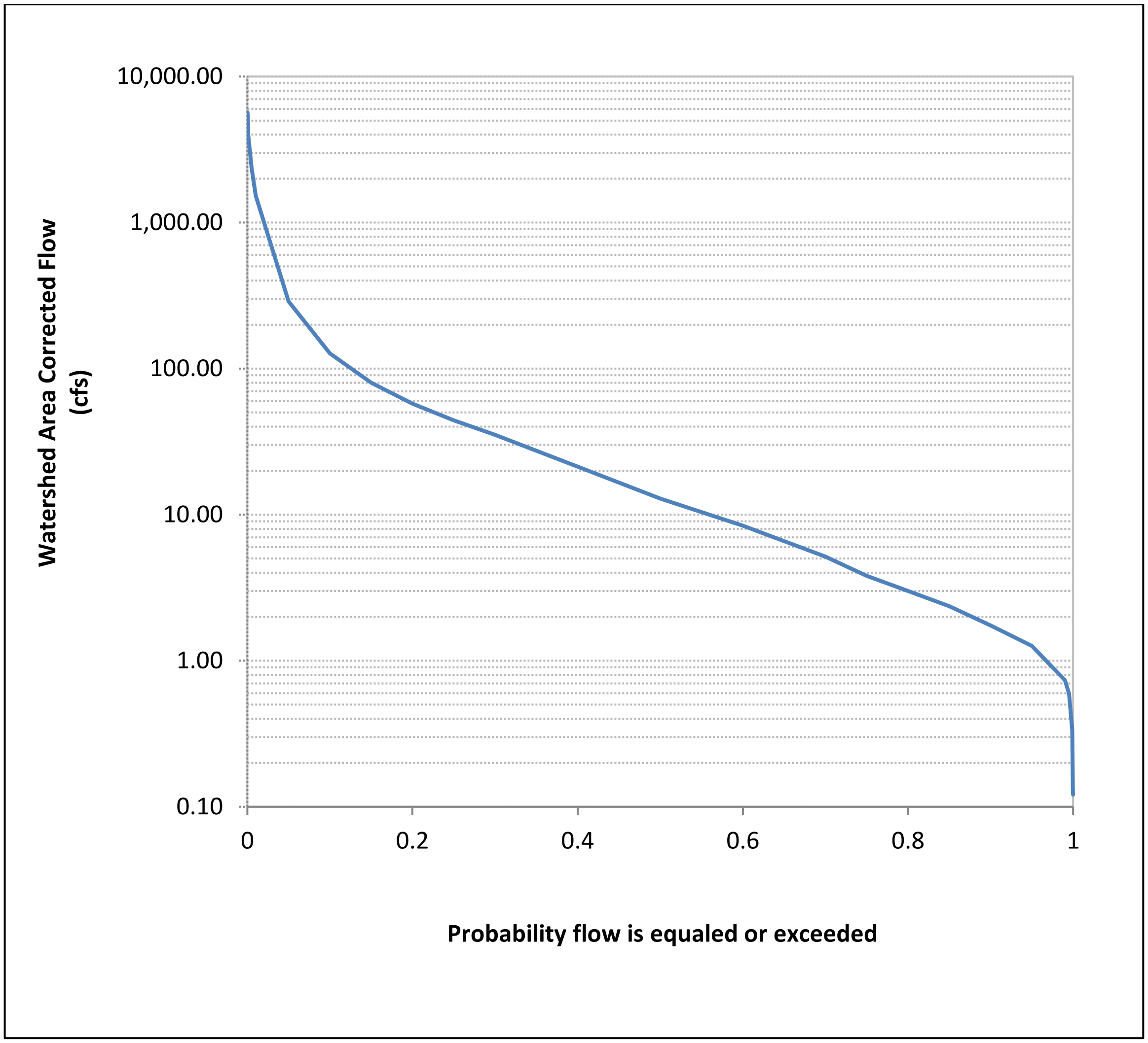

Figure B2. Little Medicine Creek, WBID 623, flow duration curve